Title

T'ulbe' ich le Bubulki K'áaxo': Linear Features as Water Management at Cobá, Quintana Roo, Mexico.

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Publication Date

2024

UNIVERSITY OF CALIFORNIA
RIVERSIDE

T'ulbe' ich le Bubulki K'áaxo': Linear Features as Water Management at Cobá, Quintana Roo, Mexico

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Anthropology

by

Patrick Carr Rohrer

June 2024

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ACKNOWLEDGMENTS

This research was funded in part by the UCR Center for Ideas and Society, UC MEXUS, and the AIA Orange County Society. I also worked throughout with the Proyecto de Interacción Política del Centro de Yucatán (PIPCY) and the Proyecto del Sacbé Yaxuná-Cobá (PSYC), which were led by Drs. Travis Stanton, Traci Ardren, and Aline Magnoni, and which received funding from the National Science Foundation and other contributors. Thank you to the above leaders in the field, along with many other colleagues in the field including Nelda Issa Marengo Camacho, Stephanie Miller, Elizabeth Beckner, Ashuni Romero Butrón, César Torres Ochoa, Gustavo Novelo Rincón, Tanya Cariño Anaya, Harper Dine, and many more. Thank you to Yaxuná, Cobá, San Juan de Dios, and Nuevo Xcán community members including Don Benjamin, Ruben Herrera, Adolfo Batun, José Manuel Nah Ku, Eugenio Puuc May, Nazario May Canche, Jorge Fredy May Uh, Honorato Canul Dzib, Feliciano Dzib, Alberto May Uh, Germán Melchor Canul, Aldrid Albornoz Aguilar, Manuel Eugenio Uh, Didier Samuel Camal Pool, Javier Dzul Cahuich, and others.

There were many other indigenous Maya *ejiditarios* (community members) that aided our projects and who were truly the heart of them. These were community efforts, with each whole town coming together to discuss plans for division and rotation of labor, not only for those who helped us in the field directly, but also those who prepared and repaired traditional thatch-roofed houses, cooked meals, washed laundry, helped wash ceramic sherds, and many other tasks. They also taught us a wealth of knowledge about Maya culture and the local environment, offering emic perceptions and guidance to our work and our daily lives. In that spirit, I want to thank my *maya t'aan* (Yukatek Maya language) teachers, primarily Dr. Fidencio Briceño Chel, Gerónimo Can Tec, Gregorio Hau Caamal, Marcelina Chan Canché, Deysi Abigail Chan Canché, Felipe Kuyoc Arceo, Irma Yolanda Pomol Cahum, and others including the people of Xocén. Lessons with them not only taught me the Yukatek Maya language, but also deep cultural meanings and how the Maya interpret themselves and the world around them.

Big thanks to my dissertation committee: Drs. Travis Stanton, Karl Taube, and Kenichiro Tsukamoto. They are a great trio that each brought unique strengths to this work with their discerning feedback and insights. The same applies to the seminars I took with each of them, and to seminars with other professors at UCR like Drs. Thomas Patterson, Wendy Ashmore, Paul Ryer, Sara Becker, and others. Thanks to my classmates and comrades in those seminars and in life, especially Joshua Lieto, Theresa Heindel, Leslie Perkins, and others. Thanks also to staff members at UCR and other institutions that help facilitate so many things behind the scenes. Finally, thank you Germán Yáñez for training me in cave scuba diving and introducing me to the creatures deep within Cenote Aerolito. No doubt I am omitting many others who aided me in my long journey along the road of this research; thank you to all of those not listed here.

DEDICATION

To the memory of James "Smokey" Rohrer Jr. (1944-2010)

ABSTRACT OF THE DISSERTATION

T'ulbe' ich le Bubulki K'áaxo': Linear Features as
Water Management at Cobá, Quintana Roo, Mexico.

by

Patrick Carr Rohrer

Doctor of Philosophy, Graduate Program in Anthropology
University of California, Riverside, June 2024
Dr. Travis Stanton, Chairperson

This research concentrates on a variety of linear features at the ancient Maya site of Cobá, Quintana Roo, Mexico, and to a lesser extent at Yaxuná, Yucatán, Mexico and other smaller sites along a *sakbej* (ancient Maya road) which connects these two. Such *sakbej* themselves are one form of linear feature, while other less formal varieties include *albarradas*, *chichbe*, and *t'úubulbej*. I argue that many of these features were designed to manage the waterscape of Cobá. In some cases, *sakbej* and *chichbe* had culverts along their sides to direct rainwater towards small reservoirs, *aguadas*, or cisterns. In other cases, *t'úubulbej* served as steppingstone paths over areas prone to flooding, which allowed foot traffic over them and water to flow under them. In so doing, the ancient inhabitants of Cobá were able to navigate seasonal changes, store water through the dry season, avoid flooding complications during the rainy season, and manage wetlands for agricultural purposes. Ultimately, the city of Cobá was largely abandoned in the ninth century AD, primarily due to climate change in the form of severe droughts. Continued research on these topics aims to alleviate the current water crises in the region and seek insight toward current and looming climate change crises.

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Preface I Notes on Language, Orthography, and a Glossary of Key Terms

This dissertation contains a number of non-English words and expressions. Words in foreign languages are italicized, with the exception of titles or proper nouns. Most of these are in Spanish (*español*) or Yukatek Maya (*maya t'aan*). Yukatek and other Mayan languages have changed over the millennia from the languages of the Classic Maya hieroglyphs (predominantly Ch'olan but also some in Proto-Yukatek), but here I prefer the contemporary Yukatek language and orthography. Because Yukatek contains a number of phonemes not commonly signified in written English, Spanish, or other languages using the Latin alphabet, the representation of these sounds in said script has changed over the years since it was introduced to and adapted by the Maya. In 1984, the Comisión de Difusión del Alfabeto Maya standardized the Yukatek orthography. Most place names and other proper nouns in use for many decades or centuries prior to this standardization still maintain their original spelling, and older generations or certain regions or towns may still utilize older or variant orthographies.

Apostrophes are used in the current orthography to note either aspirated consonants or vowels with glottal stops. Most consonants in Yukatek sound akin to their counterparts in Spanish, but some are omitted (no D, F, G, H, Ñ, Q, V, or Z), while others are added and/or have aspirated or ejective variants, as the following: CH', K', P', T', TS, TS'. The X in Yukatek is a fricative-alveolar, like the SH sound in English. Vowels in Yukatek also mirror Spanish vowel sounds, but present in a greater variety of tones, either short (a), long (aa), high long (áa), intervocalic glottal stop (a'a), or glottalized word endings (a'). These distinctions are important, as a vowel tone variation or altering an aspirated consonant has the potential to change the meaning of a word entirely. In some cases, there are still regional variations that might use variant vowel tones, or replace M for N, but retain the same word meaning. In other cases, changes in aspirations or vowel tones do indeed change the meaning, as in *cháak* (rain or the rain god), *chak* (red), *ch'ak* (bed), *ch'áak* (to chop/cut), *chaak* (to sauté), and *chaak'* (to rinse).

Pluralization in Yukatek may appear complicated to an outsider. The typical manner of pluralizing a noun is to add *o'ob* to the end of the word, or simply *'ob* if the word ends in a vowel. Verbs may be conjugated in the same manner for the third-person plural (in most cases a *u* before the verb is also needed, which alone marks third-person singular). However, plural marking is optional in Yukatek (Butler 2023), and a sentence may be understood in context by the listener or reader to be about multiple subjects without necessarily using these plural markers on either noun or verb. Alternatively, it may be added to only the noun or only the verb, and not viewed as a grammatical error or omission of any sort. Therefore, this dissertation simply uses the English convention of the zero plural (e.g., fish, sheep), leaving Yukatek nouns unmodified and to be understood as singular or plural depending on context. Spanish nouns will still be pluralized, even in cases of modified Yukatek loan words, like *cenotes*.

In this dissertation I often refer to the Yucatán Peninsula as simply "the Yucatán," while dropping the article when referencing the state of Yucatán (e.g., "There are many *cenotes* throughout the Yucatán" vs "Mérida is the capital of Yucatán"). This can be a point of contention in the region, even a political one, where some peoples and communities from the neighboring states of Quintana Roo and Campeche do not wish to be lumped in with the state of Yucatán and avoid words that seem to classify themselves under such dominion. Even those living in Yucatán state may avoid the identifier *yucateco* to distance themselves from the Yucatecos who fought against the Maya during the Caste War. For example, they may prefer "*maya peninsular*" to "*maya yucateco*" to label the language in Spanish. While I am sensitive to these cultural and linguistic preferences and distinctions, I feel that in English the use of the article "the" before Yucatán is sufficient to distinguish it from the modern state name, along with the present explanation and disclaimer. The *maya t'aan* name for the region is Mayab, and I employ that term often in this research as well.

The following are a list of key terms used in this text. I will briefly define each and in some cases add commentary about their orthography, history, and/or importance. Yk indicates a Yukatek word, while Sp denotes Spanish, even if the etymological root lies elsewhere. My main reference for these is the Diccionario Introductorio by Gómez Navarrete (2009), but I also employ my own experience learning *maya t'aan* and conversing with its native speakers, as well as other dictionaries and sources when noted.

áaktun: Yk, n. grotto, cavern, cave.

áak'al: Yk, n. swamp, seasonal lake, or large *aguada*

áak'alche': Yk, n. swamp or seasonal lake thick with trees and other vegetation (also used to describe the soil therein).

aguada: Sp, n. small body of water, pond, often swampy and prone to drying out in the dry season.

ajaw: Yk, n. lord, sovereign, king/queen, governor; today translated as "*gran señor*" and occasionally a given name, precolombian *ajaw* were sovereigns, often with additional titles associated with deities, e.g., K'awiil Ajaw, lightning god lord.

albarrada: Sp, n. short wall of unworked stones, usually used to demarcate boundaries of houselots or *milpas.* The Yukatek term for *albarrada* is *koot.*

Figure I.I Collapsed *koot* or *albarrada* with barbed wire fence running along its course.

bajo: Sp, n. large low-lying swampy area, may be seasonal.

bej / *beel*: Yk, n. road or pathway, also often used metaphorically as a life path and related analogies, e.g., the common greeting "*bix a bel*" glosses as "how are you?" but literally means "how is your road?" (When appended to or following another noun or adjective, *bej* is often written as *be* or *be'*)

brecha: Sp, n. literally breach or gap, used in the Yucatán to denote a path made by cutting through the jungle vegetation. *Brechas* may be expedient and narrow, or wider and well-maintained, like the *mensuras* used as boundaries between *ejidos*. Yukatek terms for such paths include *t'ulbe* and *éek'bej*.

búuk'tun: Yk, n. hummock of raised bedrock.

cenote: Sp, n. water body exposed by a sinkhole or collapsed opening in the karst landscape that reveals a window to the water table, like a natural well. *Cenote* is derived from the Yukatek word *ts'ono'ot*, but as the former has become a very common term in the region, this dissertation will primarily refer to these water features as *cenotes*.

cháak: Yk, n. rain, storm, the rain god; *táan u k'áaxal cháak*: it is raining; *pek cháak*: thunder; *jaats' cháak*: lightning; *me'ex cháak*: moss, lichen, literally "beard of Cháak."

Importantly, the word *cháak* on its own can mean the rain god, and thus may be understood to be a personification of rain and storms. However, *cháak* is not commonly used today in Yukatek to express "rain" in everyday language. The more common expression for rain as a weather phenomenon is *k'áaxal ja'*, and terms for rainwater include *ch'ulub ja'* and *ka'anil ja'* (see below).

che': Yk, n. tree.

chichbe(t): Yk, v. to guide, direct, channel, route. (see *ch'ich'*, below)

chultun: Yk, n. cistern made by carving out soft limestone bedrock.

ch'a' cháak: Yk, n. ritual ceremony for rain petition and thus bountiful harvest.

ch'e'en: Yk, n. well, as in a shaft in the ground used to draw water; no distinction is made between anthropogenic wells vs "natural wells" like *cenotes*, any opening to the water table that is used like a well may be called *ch'e'en.*

ch'ich': Yk, n. pebbles, small rocks, cobble, or gravel.

This definition is found in earlier dictionaries, e.g., the Diccionario Maya Cordemex (Barrera Vásquez 1980), which pulls from still earlier sources like the Diccionario de Motul (Ciudad Real 1577). In the Cordemex, this is the third of four entries for *ch'ich'*, each with their own numerous definitions. The first two deal with birds (*ch'íich'* in contemporary orthography), while the fourth references convulsions and seizures. Still, this third entry of "small rocks" seems a good fit for archaeological features of piles of the same, even if it is no longer a common term today. No speakers I asked were aware of this definition but offered other terms to describe "*ch'ich'* mounds," including *mulu'uch* (rocky mound), *tunichil túutuk* (rock pile) or *juntukub tunich* (one pile of stones). However, the entry for *guijarro* (pebble) in the Diccionario Introductorio (Gómez Navarrete 2009) is *ch'ich'il tuun*.

Unfortunately, most archaeological literature uses the spelling "*chich* mounds" without apostrophes to mark the aspirated CH', and *chich* means "hard/strong" (and many synonyms and variant usages thereof) or "grandmother" (*chiich* in modern orthography). More unfortunate still, the neologism *chichbe* meant to convey "*ch'ich'* road" could actually mean "gossip" or, more pointedly, "nosy informant who spies on others' lives" if we stick with the proper rendering of *ch'ich' be*. However, in a twist of good fortune, *chichbe* without the aspirated CH' is a verb most often conjugated as *chichbetaj* or *chichtaj be*, meaning "to guide, direct, channel," which turns out to be a good fit for the linear features known as *chichbe*, as I will explain in this research. Of course, this only makes sense if we allow for the conversion of this complex verb construction into a noun form, customarily realized in Yukatek through affixing *-il* to the end of the word, but in rarer cases left as is. Therefore, this dissertation will use *ch'ich'* to describe such mounds, construction fill, or other instances of groups of small stones, but *chichbe* to reference the linear features at Cobá and elsewhere.

ch'ulub ja': Yk, n. rainwater.

ejido: Sp, n. communal agricultural land and villages used by indigenous peoples in Mexico, in which the *ejiditarios* (community members of an *ejido*) have usufruct rights to said land in place of private ownership.

ixi'im: Yk, n. corn, maize; *ixi'im* is the general term for corn, though it is referred to with specific words when in various forms (see *nal*, below).

ja': Yk, n. water.

ja'ab: Yk, n. year.

ja'ja'ab / *ja'aja'al* / *ja'ja'lil*: Yk, n. the rainy season.

jaats'ab ja': Yk, n. downpour, heavy rain.

jaltun: Yk, n. small depression or opening in the bedrock or large stone where rainwater accumulates. In Spanish these are *sartenejas*, though constructed ones that look like *metates* but with deeper pits in them to collect water are known as *pilas*.

Figure I.II Small *jaltun* filled with *ka'anil ja'* (rainwater) at the edge of a *cenote* (in background far below).

jolch'ak: Yk, n. to cut a path, to make a *brecha*.

jool: Yk, 1. n. hole, opening, pit, cavity, hollow. 2. v. to clear the way, open a path; to bore a hole in, perforate.

kaab: Yk, 1. n. land, earth; *yóok'ol kaab*: world. 2. n. bee, honey; *ko'olel kaab*: melipona bee.

ka': Yk, n. a stone with a concave depression or shape, used as a surface for grinding maize or other food processing with a *mano* (grinding stone). *Ka'* is *metate* in Spanish, via the Nahuatl *métatl*.

kaajal: Yk, n. town, population.

ka'anil ja': Yk, n. rainwater.

kool: Yk, n. an agricultural plot, often using a swidden crop system. Known as *milpa* in Spanish, derived from the Classic Nahuatl *mīlpan*.

ko'op: Yk, n. a karst depression from a sinkhole that is filled enough (with rock, soil, and vegetation) to not connect to the water table, but the base of this depression nears the water table and often fills with rainwater during the rainy season. The Spanish term for this feature is a *rejollada*.

koot: Yk, n. (see *albarrada*, above)

kuchkabal: Yk, n. region, polity, province; typical state political organization of Postclassic Mayab.

k'áax: Yk, n. forest, jungle, wilds. While primarily used to refer to the jungle, *k'áax* may refer to any wild or undomesticated space. This is reflected in similar terms, e.g., the adjective "wild" is *k'áaxil*.

k'ank'ubul: Yk, n. yellowish sky said to bring hot rain that burns the crops.

lak: Yk, n. ceramic plate; *cajete*; can also signify ceramic sherds or pottery in a general sense, though some forms may have (or had) more specific words, as *uk'ib*: drinking vessel.

lu'um: Yk, n. land, dirt, soil. (further terms for soil classification discussed in Chapter 4)

metate: Sp, n. (see *ka'*, above)

milpa: Sp, n. (see *kool*, above)

múul: Yk, n. hill, mound; used to describe ancient structures that are now covered in jungle and appear as earthen mounds. Notably, the term is often retained even after such structures are consolidated and restored, as in Nohoch Muul at Cobá.

nal: Yk, n. corn on the cob, ear of corn, *elote*; sometimes used to refer to particular maize cultivars, as *xnuuk nal*, a white variety that matures after four months.

petén: Yk, n. island, region, province; *péetlu'umil*: state

rejollada: Sp, n. (see *ko'op*, above) *sa'ap'ak*: Yk, v. to dry up, as a well or *aguada*

sakbej: Yk, n. white road, human constructed road. Often written *sacbe* in the older orthography. Inscribed stone markers along Sakbej 1 suggest that the ancient Ch'olan Maya word was similar, *sakbih* (Stuart 2006), but in this work I will use *sakbej* for continuity and familiarity.

saskab: Yk, n. soft white powdery limestone used to produce lime plaster, mixed into mortar for construction, or added to pottery. Rendered *sascab* in Spanish, quarries of it are known as *sascaberas*.

sarteneja: Sp, n. (see *jaltun*, above).

Interestingly, the folk etymology of the fishing village of Sarteneja, Belize holds that it derives from the Yukatek *ts'áajten a ja'* = "give me your water," though the general term *sarteneja* appears to originate from a diminutive of the Spanish *sartén* (frying pan, but also "circular hollow" in antiquated usage), likely via the Late Latin *sartāginem* (Corominas 1980:172). In Galician, *sartego* (alternative form: *sartén*) as a noun can mean either an ancient stone sarcophagus, sepulcher, or a subterranean chamber of a water mill, and means stony as an adjective.

sim tun: Yk, n. obsidian. Note: The Cordemex (Barrera Vásquez 1980) lists additional definitions having to do with burnt stones used for cooking or sweat baths, leading me to believe *sim tun* has more to do with blackened, heat-treated, and/or calcined stone than with obsidian, at least originally.

sujuy ja': Yk, n. virgin or untouched water collected from clandestine *cenotes* (often small and/or within caves) and used for rituals; in some regions known as *ta'akumbil ja'* (hidden water).

toj: Yk, adj. straight, direct; *toj in wóol* = "straight my heart/soul," meaning "I am healthy and sound in body and mind."

tok': Yk, 1. n. chert, flint; sometimes elaborated as *tok' tuunich*: flint stone. 2. v. to prick, pierce, make bleed.

While there are entries in dictionaries for obsidian such as *sim tun* (see above), I have not encountered native speakers aware of such a term, and indeed some are also unaware of the Spanish word *obsidiana*. This is understandable, considering volcanic glass is not geologically local to the flat northern Yucatán, and obsidian is mainly encountered there today at museums, while excavating, or at tourist markets. Considering the double meaning of *tok'* as a verb for piercing to draw blood, it is possible that both chert and obsidian were known as *tok'* in epochs past, perhaps with additional adjectives to distinguish them. *Ets'nab*, a *tzolki'n* calendar day name, was the term for sacrificial blade, literally "sharp lance/blade," presumed to be chert.

tooj: Yk, n. turquoise-browed motmot bird (*Eumomota superciliosa*), common in and near *cenotes*.

tuunich: Yk, n. stone or rock (sometimes shortened to *tuun* or *tun*, especially when combined with other words and adjectives, as in *ya'ax tuun*, jade).

t'ulbe: Yk, n. pathway through the jungle, trail, *brecha* (see above).

t'úubulbej: Yk, n. literally "soaked/flooded/plunged road," a road that is partially submerged or inundated; steppingstone boulder paths through low-lying areas that may be seasonally flooded; related, *t'úubul k'iin*: sunset, literally "sinking/plunging sun."

In full disclosure, I arrived at this term through the need to describe a particular type of linear feature found in the archaeological record, thus it could be considered a neologism. Other authors (Hixson 2011; Leonard 2013; Magnoni et al. 2012) have used the Spanish *andador* (walkway) to describe similar features, but to me *andador* does not distinguish these features from any other walkway or road, and thus has led to some confusion.

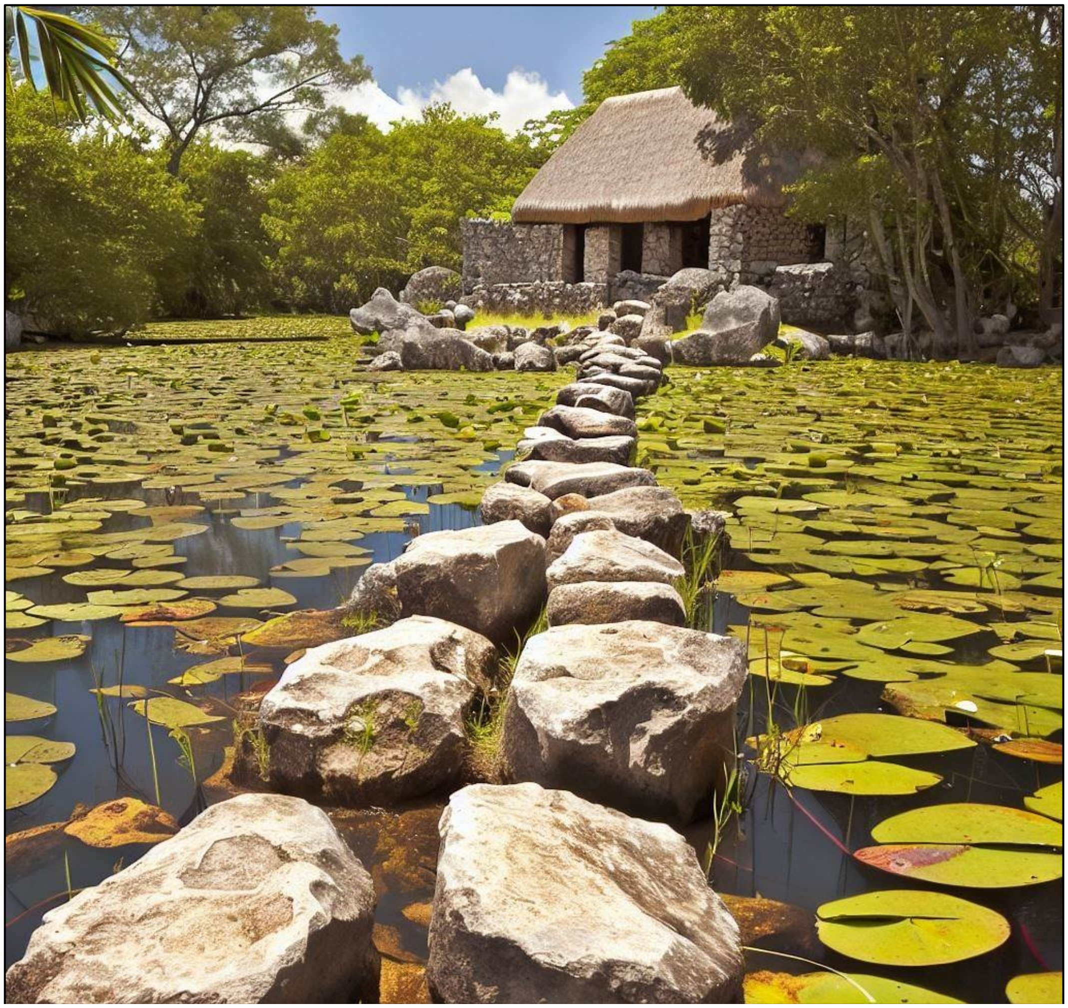

Figure I.III Idealized artistic representation of a *t'úubulbej* surrounded by water and water lilies and leading to a small houselot. Image created and edited by author with the aid of image generator software.

When I asked native speakers, most responses were that if it is a road or path, it is a *bej*, and if a rough jungle path, it is a *t'ulbe*. However, when pressed further about how to specifically describe a steppingstone boulder path that is partially flooded, a few times I was offered the phrase "*tun t'úubul bej*," a road of inundated/plunged stones. Considering that the other paths/roads discussed herein (*sakbej* and *chichbe*) are also understood to contain *tun* (stones), I feel it is acceptable to use the shorthand of the combined final two words, thus *t'úubulbej*. This term is not to my knowledge extant in any archaeological or Mayanist literature, is not a common expression in Yukatek, but is understood by at least some native speakers.

Furthermore, the Cordemex (Barrera Vásquez 1980:843) lists "*t'ubul be*" as *camino derecho*, straight/direct/right path; "*t'ubul be a benel ka' achak a sa'tal*: *anda por camino derecho para que no te pierdas* [walk on the right path so you don't get lost]." While I began this preface with a warning about altering vowel variations and aspirated consonants, the Cordemex was written before the 1984 orthography was established, and routinely lists words that have long or high vowels as short vowels, or otherwise mixes these up, understandable considering the wide variation in orthography from the many early sources from which it pulls. Many of the *t'úubulbej* I am classifying are not very straight, but curvy and winding. However, they often provide a direct path from one place to another along a raised walkway, perhaps to prevent getting lost in the jungle, though more likely to prevent trudging through water and mud.

tsek: Yk, n. foundations of a house, either of ancient structures or of contemporary traditional homes whose walls and roofs are built of perishable materials.

tsek'el: Yk, n. rocky soil unsuitable for farming; hillock of weathered limestone.

ts'aats': Yk, n. a depression formed by a sinkhole that touches the water table but does not penetrate it enough to form a *cenote*, resulting in a permanent water source but one that is often shallow, murky, turbid, or even swampy. *Ts'aats'* can be conceptualized as a geoform in between a *rejollada* and a *cenote*.

ts'ono'ot: Yk, n. (see *cenote*, above)

uk'ib: Yk, n. ceramic drinking vessel.

úuchben: Yk, n. old, ancient.

ya'ax che': Yk, n. ceiba tree, literally "green tree."

Preface II Chronologies and Geography

The Maya and other Mesoamerican societies have long ranging histories that archaeologists and historians have sectioned into epochs, phases, or periods (Table II.I). The names and date ranges of these periods have changed over time as more data, new understandings (e.g., of hieroglyphic writing systems), and new and more precise radiometric dating techniques have been applied and analyzed. Such epochs are heuristic devices for demarcating shifts in past material culture that are not necessarily (undoubtably very rarely) reflections of emic understandings of cultural ages. Instead, these distinctions developed around the etic notion of the Classic Maya, an age when many large cities and polities rose to prominence with monumental architecture and stelae carved with glyphic inscriptions chiefly relating the accomplishments of their *ajaw* and wars with other sovereignties.

The Maya cultural sphere (often referred to as the Mundo Maya) is also vast geographically (Figure II.I), covering all of contemporary Guatemala, portions of western Honduras and El Salvador, and five states of southern Mexico. It is thus not realistic to drape blanket temporal eras over the entire region and expect them to fit and make sense for the development and trajectory of varied regions and sites. Still, these periods are heavily engrained in Mayanist literature and thus difficult to ignore or avoid, and they do delimit material markers of cultural change, even if they are not universal or emically marked. Therefore, I here outline their usage in this dissertation and then discuss some site-specific chronologies of Cobá and Yaxuná.

Period	Approximate Date Ranges	Hallmarks of Cultural Change
Paleoindian	20,000 - 8,000BC	First Peoples of the Americas
Archaic	8,000 - 2,000BC	Agriculture and Settled Communities
Early Formative	2,000 - 1,000BC	Distinct Maya Art/Architecture, Complex Societies
Middle Formative	1,000 - 350BC	Increased Socieconomic Complexity and Heirarchy
Late Formative	350BC - 150AD	Large States Form, Population Increase
Terminal Formative	150 - 250AD	Decline and Transformation of States
Early Classic	250 - 600AD	Expansion of Lowland States
Late Classic	600 - 800AD	Apogee of Lowland States
Terminal Classic	800 - 950AD	Decline and Transformation of States
Early Postclassic	950 - 1200AD	Reformulation and Revival of States
Late Postclassic	1200 - 1511AD	Reorganization of States/Kingdoms
Spanish Contact	1511 - 1697AD	Spanish Conquest of Maya Kingdoms
Colonial	1697 - 1821AD	Colonial Rule

Table II.I Maya chronology, in part after Sharer (2006:98, Table 2.2)

Maya chronology is grouped into the following main periods (Table II.I): Formative (also known as Preclassic), Classic, Postclassic (unfortunately formerly called the Decadent by some), and Colonial. Within these are further subcategories, and they are predated by the Paleoindian and Archaic, which are not specific to the Maya. While this table ends with 1821, the Maya did not disappear after this date any more than they did at the end of the Classic Period, often referred to as the Maya "collapse" and leading to popularized and sensationalized takes about the "disappearance" of the Maya. The Maya continue today eight million strong, thriving and having survived the *ba'atabil kichkelem Yúum* (Caste War of Yucatán, 1847-1915) and the Guatemalan Civil War (1960-1996), amongst other challenges and difficulties.

The primary foci of this dissertation pertain mostly to the Classic Period, as one of the main questions concerns that "collapse" or decline and abandonment of many Maya cities during and around the Terminal Classic. However, I do touch on the Formative to set the stage for the development of Maya settlements, and also discuss more recent history and current Maya culture in order to apply these lessons from the past to contemporary crises.

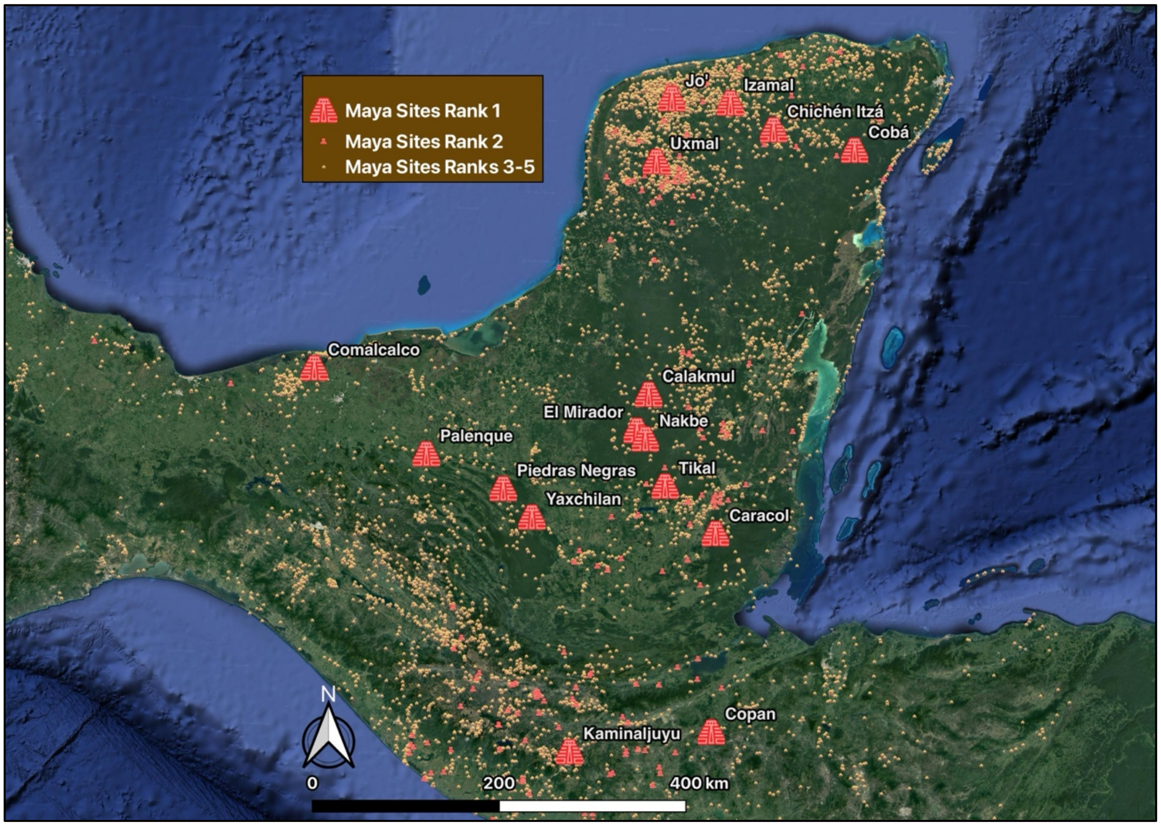

Figure II.I Primary extent of Maya cultural sphere, or the Mundo Maya.

The geographic concentrations of this research are the cities of Cobá, Yaxuná, and sites along Sakbej 1, the ancient road that connects these two cities (Figure II.II). In Table II.II we can see a breakdown of the site-specific periods of these cities, other sites in the region of the northern Yucatán, and a couple from the Petén region - namely Tikal and Uaxactun - for comparison. These local periods are predominantly based on ceramic complexes, assemblages of the dominant ceramic types through those time period ranges, determined by stratigraphy and radiometric dating. When discussing temporal changes at these sites, I prefer to use their localized complexes for better accuracy and precision but will also reference the broader Maya timeline. In some cases, I reference complexes from sites not included in Table II.II, in which case I include a citation and date range.

Figure II.II Map of the northeast Yucatán Peninsula, exhibiting the *sakbej* that connects Yaxuná to Cobá.

We also have glyphic inscriptions at many of these sites with dates in the Maya calendar system that we can decipher and translate to our Gregorian calendar, often to the day. Alas, these are far scarcer and often more eroded in the northern Yucatán than at many of the cities of the Petén and elsewhere in the south - Copán, for example. Ek' Balam and Cobá are notable exceptions to this trend, though many of the stelae at Cobá are indeed heavily eroded. The history of Cobá revealed in these glyphs will be detailed further in Chapter 5, but for now I will mention that dynastic rule of Cobá appears to begin roughly 500AD and end in 780AD, based on these stelae (Con Uribe and Esparza Olguín 2017; Esparza Olguín 2020; Guenter 2014). No such dated monuments or named dynasts have been uncovered at Yaxuná.

	Tikal	Uaxactún	Mayapán	Dzibilchaltún	Chichén Itzá	Yaxuná	Ek Balam	Cobá	Oxkintok
A.D. 1400					Tases				
A.D. 1350			Tases						Tokoy III
A.D. 1300						Yaxuná V		Seco	
A.D. 1250			Hocaba		Hocaba		Xtabay		Tokoy II
A.D. 1200									
A.D. 1150									
A.D. 1100			Sotuta						Tokoy I
A.D. 1050					Sotuta				
A.D. 1000									
A.D. 950						Yaxuná IVb			
A.D. 900	Eznab		Cehpech					Oro	Ukmul II
A.D. 850		Tepeu III			Huuntun		Late Yumcab		
A.D. 800				Copo					Ukmul I
A.D. 750	Imix	Tepeu II			Yabnal	Yaxuná IVa			
A.D. 700			Motul						Noheb
A.D. 650	Ik							Palmas	
A.D. 600		Tepeu I				Yaxuná III	Early Yumcab		Oxkintok Regional
A.D. 550	Manik IIIb								
A.D. 500					Cochuah				
A.D. 450	Manik IIIa		Cochuah					Blanco	
A.D. 400		Tzakol		Piim		Yaxuná II			Ichpa
A.D. 350	Manik II								
A.D. 300							Alux		
A.D. 250	Manik I								
A.D. 200	Cimi							Añejo	
A.D. 150					?				
A.D. 100				Xculul		Yaxuná Ic			
A.D. 50									
0	Cauac								But
50 B.C.		Chicanel							
100 B.C.									
150 B.C.						Yaxuná Ib			
200 B.C.	Chuen			Komchen					
250 B.C.							Manab		
300 B.C.									
350 B.C.			Tihosuco		Tihosuco				
400 B.C.	Tzec			Nabanché II					Sihil
450 B.C.		Mamon							
500 B.C.									
550 B.C.							Balam		
600 B.C.	Eb					Yaxuná Ia			
650 B.C.				Nabanché I					
700 B.C.									
750 B.C.									
800 B.C.									
850 B.C.									
900 B.C.									
950 B.C.									
1000 B.C.									

Table II.II Chronology of Cobá, Yaxuná, and other lowland Maya sites (after Tiesler et al. 2017:28)

Chapter 1 Research Setting, Questions, and Goals

1.1 Káajbal (Introduction)

Walking along a well-trod *brecha* through the jungle, my Maya companions and I hear the haunting echo of the call of the *tooj* bird reverberating against the limestone walls of the *ts'aats'* (sinkhole) before we see it. The day is hot and the air still, the hum of insects mingles with other bird calls and lizards rustling in the bush. As we near the *ts'aats'*, the air cools and feels fresher, though the smell of mushrooms and decaying plant life grows sharper. From the western edge we can see a few large mounds, a small complex of structures, and a double line of *t'úubulbej* (steppingstones) connecting them. From the lidar DEM map on my tablet I know we are also close to a host of other large mounds and a *sakbej* (white road) leading to the monumental termini complex known as Kitamna ("peccary house"), but they are all hidden in the jungle from our vantage point. Turning towards the *ts'aats'*, a rickety wooden staircase presents the route of our descent, built in recent decades atop a much earlier stone staircase that now sits as a large pile overgrown with the roots of large trees and other vegetation (Figure 1.1). Roughly 15m below, we are greeted by other contemporary structures - a viewing pavilion and half of a mockup of a Maya ballcourt are seated atop and beside earlier stone platforms and a stone altar. I plunge my hands into the cold water along the southern edge beside some water lilies, splash some on my face and neck, and begin to pick out an ideal spot for a test pit excavation.

Figure 1.1 Wooden staircase built atop ancient stone stairway to access Dzadz Iox.

This scene of a morning of field research and work at the ancient Maya site of Cobá in 2018 encapsulates much of what this dissertation is about. The *ts'aats'* near Kitamna - named Dzadz Ion - tells a story both ancient and modern of relationships between the Maya and such water sources. The modern constructions were short-lived, built around the mid 2000s and abandoned by the early 2010s, perhaps not drawing in enough tourist dollars for the effort to maintain and run the show. Some 1,400 years earlier, rituals and perhaps public "shows" of a sort were likely performed in the same spot, perhaps focusing on rites of supplication to the rain god Cháak to continue to water the *kool*, the cacao, and to replenish the aquifer present in the southern end of the *ts'aats'*. Eventually, however, the rains came less often and less plentiful, and the ancient Maya likewise abandoned their practices in the relatively drier conditions of this *ts'aats'* in the ninth and tenth centuries AD.

Cobá was not completely abandoned in those centuries, labeled the Terminal Classic (see Preface II), but it and many other mighty Maya cities and polities saw an abrupt alteration to their political and economic regimes, a ceasing of long reigning dynastic lineages, and often a significant demographic loss if not near complete abandonment, all totaling the "Maya Collapse" that resulted in so many majestic cities being taken back by the jungle and hidden from the eyes of conquering Spaniards and later explorers for so many centuries. Even today we are still discovering entire cities and other large settlements with the aid of lidar technology. Of course, Maya people, culture, and society did not "disappear" then or ever. More than eight million Maya people continue their traditions today throughout their historical homelands and beyond.

Questions remain, however, about the catalysts and nature of the abandonments and political shifts.

Therefore, in this research I contemplate why some sites and communities were largely abandoned while others survived or even flourished. What were the conditions that allowed some Maya to thrive? To answer this, I will discuss ancient water management strategies, vulnerabilities, and resilience in the face of major droughts, and the use of linear features to control and direct both rainwater and foot traffic in the ancient Maya cities of Cobá, Yaxuná, and the settlements along Sakbej 1, an almost 100km road that connects them. The data collected for this research emanate from ground survey and excavations on days described above, and many hours working with lidar data to piece together patterns from beyond the ground surveyed areas. In both cases, chronology is paramount to the archaeological data - the palimpsest nature of the lidar maps and the many layers of deposition during the long occupation of these sites, up to and including contemporary structures built for tourist shows and recently abandoned, housing for the current inhabitants and hotels, and albarradas for recent seasons of milpas to grow both ancient indigenous crops like corn, beans, squash, and chiles, and arrivals of more recent centuries like watermelon, bananas, and mangos.

As ever, contemporary Maya at Cobá rely on the rainy season to grow these plants. In 2018 the rainy season began strong, flooding the parking lot for the archaeology zone open to tourists and swelling the lakes to encroach upon the roads and swallow stretches of older roads known as *sakbej*. The croaking of frogs during and after these heavy rains was almost deafening at times, but musical and calming. When the deluge let up and work continued, many pockets of small seasonal aguadas and catchments were filled with water that would dry up later in the season, percolating through the limestone to the aquifer below or following the many worn holes in the karst bedrock like so much Swiss cheese. The following summer of 2019, the rains were late and infrequent, leaving Lake Cobá reduced to a fraction of its surface area from the previous year and highlighting the pronounced and acute changes to that environment from season to season and year to year.

Some of the threats to this environment and these natural resources are relatively new: intensified climate change from carbon emissions, massive pollution from pig farms, and industrialized cities. Other impediments are the same or similar as ancient problems: flooding and storm damage from hurricanes or other persistent thunderstorms, long spells of drought and thus lack of crops, and simpler pollution in the form of human and animal waste that makes its way into the aquifer. Therefore, learning about past water management strategies and varied successes and failures in the face of similar crises may aid us in dealing with modern conservation efforts and climate change.

1.2 Maya Wíinik (Maya People)

Who are the Maya of the past and present? Early scholars of the ancient Maya tended to either instill them with the Noble Savage treatment, regarding them as peaceful farmers and priest-astronomers (e.g., Thompson 1963) at one with nature or, conversely, as bloodthirsty warriors concerned primarily with human sacrifice and victory in battle. Scholars today take a more nuanced approach and explore many aspects of ancient Maya society and culture - the good, the bad, and the ugly. Nevertheless, such oversimplistic views still persist in popular culture, thrilling and impressing tourists with stories and caricatures of Maya people to create a monolithic image. We know, however, that the cultural and linguistic group we call the Maya spans millennia (continuing today) and hundreds of thousands of square kilometers, and thus represents a multitude of vastly diverse voices, ideas, communities, expressions, art styles, and lifeways. My research aims to offer a comparison of various types of communities and social organization and their differing strategies of water management, environmental relationships, and levels of resilience in the face of climate changes.

1.3 Ja' yéetel Lu'um (Water and Land)

Waterscapes and landscapes of the Maya world offer a variety of environmental challenges and opportunities from mountainous rainforests to drier flat coastal regions, with a wide range of water features and disparate annual rainfall. Throughout the Maya area, water sources were (and still are) a marker of identity and community (Palka 2014; Scarborough and Lucero 2010). Though found in many areas, *cenotes* are far more abundant and important in determining settlement patterns in the Northern Yucatán than in other regions of the Maya realm, and often their cosmological and ideological significance was wrapped up in their utilitarian and life-giving functions (Brown 2005). Water also varies seasonally throughout the mostly tropical Maya region, where it may be overabundant in the rainy season (particularly through heavy monsoons or hurricanes) but scarce in the dry season (especially through long droughts). Accordingly, water must be managed carefully (Ashmore 2015:314) for both potability and agricultural distribution. When it was not, it could have deleterious consequences.

Precipitation, general climate, and environmental history are also important to consider in the waxing and waning of settlement patterns in any region. Agrarian urban centers thrived for centuries in Mesoamerica (Fletcher 2009), but many Maya cities were heavily depopulated and saw their hegemonies crumble in the ninth and tenth centuries AD. Was their decline due to internal conflicts, external human forces like warfare, external environmental forces like drought or other long term climate changes, or something else?

We know there is no such thing as a pristine untouched forest or habitat (Roberts et al. 2017), but which past human alterations to the tropics worked and which failed? Rather than fall into the trap of the ecologically noble savage (Hames 2007), we must recognize the diversity of past human relationships with the environment and admit that some were quite detrimental and disadvantageous. How then do we learn from past failures and successes?

I address this question through the study of ancient communities of various scales and types at the ancient Maya sites of Cobá, Yaxuná, and smaller settlements along a 100km long *sakbej* which connects them. Even just along this 100km corridor, the localized environment can be sharply different, especially in geological and hydrological differences. Political, economic, and social differences existed as well, from the large center of Cobá as the capital of powerful kingdom to small hamlets and hinterland settlements with much smaller populations. By analyzing the differences in both the environmental makeup and human community settlement patterns, and how they interacted and influenced one another, we can begin to learn more about the Maya relationship with the environment and climate change.

1.4 Annotated Table of Contents

Chapter 2 lays down a framework of anthropological thought and outlines theoretical approaches to the research. The main objectives of this chapter are to a) review past theories and perspectives of the role of water management in human societies and the historical arc of those views and b) frame the research in an anthropological lens geared towards understanding the role and influence of hydrological cycles and climate changes on societies, and vice versa: i.e., the impact of humans on water systems and climate. These perspectives are broad, ranging from considerations of resilience in socio-ecological systems, to the role of water management in state formation and urbanism, to ideas surrounding communities at various scales, to matters of identity and ideology as they relate to water management. Though varied, each of these pieces are important aspects of my contemplations of this research which influence all of the rest, and I draw connections between the pieces at the end of the chapter.

Chapter 3 introduces the Maya cultural perspective toward water bodies and caves. Maya linguistic categories and nuances demonstrate their relationship toward these features. Through studying Maya iconography, epigraphy, ethnohistory, we may better appreciate their interactions with water and hydrological systems and features. The built environment and material record also reflect relationships with water deities, rain, and the waterscape.

Chapter 4 details the hydrology of the Yucatán Peninsula as influenced by its karst geography and soil profiles. This chapter not only discusses this geological makeup from a western perspective, but also details Yukatek Maya terms and categories for landscape and waterscape features, both built and natural. The predominance of these kinds of features in the landscape was extremely important in the formation of Maya cities and communities.

Chapter 5 relates the adaptations that Maya peoples utilized in various regions to facilitate life and agricultural methods, especially regarding water management. In addition to initial adaptations, this chapter focuses on major droughts and climate changes at different epochs, and how the Maya delt with those changes. The culture histories of major sites in this research are also here discussed, namely Yaxuná, Cobá, sites along Sakbej 1, and sites in neighboring regions like Yalahau.

Chapter 6 breaks down the methodological tools used to collect and analyze data for this research. Lidar data were a major source, and I recount how and when they were collected along with the many features that I digitized and analyzed through varied strategies with these lidar maps. Survey and excavation were also very important, and I detail these methods and reasoning for choice of excavation locations. I also collected water samples for testing, and I lay out the analysis methods for those samples and for all artifacts found in the excavations.

Chapters 7 and 8 contain the raw meat of this dissertation, namely the data in the forms of test pit excavation notes, drawings, diagrams, and results, artifact photos and analysis, lidar maps and digitized features, heatmaps, flow accumulation map, and water quality data. In each section I briefly analyze the surface meanings of these datasets and connect the meanings of one to another throughout the chapter and especially at the end.

Chapter 9 dives deeper into the examinations from the previous chapter and simultaneously broadens to scope as to the wider meanings of this research while also narrowing in greater detail to meticulous aspects of the data. The linear features that became so important in this research are highlighted in relation to water management and connected to settlement patterns and agricultural strategies. Finally, I discuss how all of these data impact discussions of Maya adaptations to drought and climate changes.

Chapter 10 wraps up our story and applies it to the wider and contemporary world, while emphasizing the particular predicament of water issues of the aquifer of Yucatán Peninsula today. Water scarcity and water management problems are as relevant as ever, and we must learn from the mistakes and successes of the past to flourish now.

Chapter 2 Theoretical Perspectives

ποταμοῖσι τοῖσιν αὐτοῖσιν ἐμβαίνουσιν, ἕτερα καὶ ἕτερα ὕδατα ἐπιρρεῖ
Potamoisi toisin autoisin embainousin hetera kai hetera hudata epirrei
"On those stepping into rivers, different and different waters flow."
-Heraclitus via Cleanthes from Arius Dedymus from Eusebius (Reinhardt 1916:177)

2.1 Introduction

Rushing water as a symbol for change (water and change being two core concepts of the work here presented) dates back at least to the fifth century BC with Heraclitus' *Fluß* (Reinhardt 1916) and likely far beyond. Water permeates and heavily comprises the bulk of all living things, while also strongly influencing non-organic matter. It is also continuously changing through the hydrological cycle, making water a challenge to study in the archaeological record, leading to its classification as a hyperfact (Normark 2014) instead of one of the more commonly recognized categories of artifacts, ecofacts, and features. The omnipresence of water makes it all the more critical to study. This chapter will review theoretical frameworks regarding ecology, resilience, climate change, community, governmentality, nature vs. culture, ideology, identity, and how they all relate to water management and social changes. When we discuss all of these theoretical considerations and social categories, it is imperative not to lose sight of the environmental and historical particularities of the Maya region, and, most importantly, the Maya people themselves, including their culture, cosmology, language, and ethnoecology, all subjects of the subsequent chapter.

2.2 Climate Change and Ecology

Anthropogenic global climate change spawned by carbon emissions and chemical pollutants since the rise of the Industrial Revolution is an historically particular and relatively recent phenomenon (Vitousek et al. 1997), but detrimental anthropogenic alterations to the environment are by no means exclusive to the contemporary world. For example, deforestation through human activity has exacerbated the impact of extant cycles of drought in Mayab for millennia (Beach et al. 2008; Cook et al. 2012; Griffin et al. 2014). The complex interaction of ecological cycles and human modifications to the landscape by the Maya throughout their history has been dubbed the "Mayacene" by Timothy Beach and his colleagues (2015). This is not unique to the Maya region. Ecological systems and human societies have undergone incredible transformations and jockeyed for stability and survival throughout history and in many different ways the world over.

To frame the overlap of ecological systems and human societies, it is helpful to consider the work of Murray Bookchin (1982) on social ecology, which combines dialectical thinking with an ecological perspective. Humans are part of the natural world, and, according to Bookchin, hierarchical forms of domination in human societies are harmful not only to humans but to the environment, and often one harm perpetuates the other. In other words, environmental issues are fundamentally social issues, including climate crises both past and present, and the best way to overcome them is to foster an "ecology of freedom" (Bookchin 1982). Now, this is rather idealistic and has been critiqued as utopian, and for better or worse many hierarchical societies have thrived despite depredating the environment of which they are a part, but such an outlook is not always sustainable.

When it comes to the question of adaptation and survival through climate crises, the primary factor is one of resilience, both of ecological systems and of human cultures, social organizations, and strategies. Ecological resilience is the ability of an environmental system to either return to a healthy equilibrium after a damaging disturbance or absorb such a disturbance and still continue to operate and support the same fundamental elements and parts of its makeup as before (Folke et al. 2004; Holling 1973). Previous research (Walker et al. 2004) in socio-ecological resilience has identified and described four key elements to evaluate such hardiness: 1) Latitude – the maximum threshold that a system can handle before reaching a critical mass and not being able to recover as such; 2) Resistance – a measure of the intensity of the perturbation necessary to alter the course of a system; 3) Precariousness – the proximity of a system to the maximum threshold described within latitude, and its current trajectory toward or away from that threshold; and 4) Panarchy: the influence of subsystems and related states on the other three elements of latitude, resistance, and precariousness. Once again, these principles can be applied to systems beyond ecological systems, such as businesses, societies themselves, economic systems, and other social organizations.

However, this is not to imagine that such systems can be boiled down to mathematical equations or algorithms, nor to repeat the past mistakes of past archaeologists overly focused on systems theory (see Salmon 1978). For the present research (and my stance in general), the above elements of resilience merely serve as heuristic devices to pinpoint and discuss human attempts to bolster ecosystems and to adapt to climate changes that we can identify in the material record. Observing these in the past has the potential to guide our efforts to do so in the future. Wahl's (2016) call to action to design regenerative cultures looks within and reflects on ways for human societies to adapt, to think differently, and to consider cooperation over competition to curb ecological disasters like biodiversity loss and declining global freshwater, without fixating on overpopulation but instead seeking to find and change maladaptive and even self-destructive aspects of human systems.

Climate resilience, more specifically, is similar to the above considerations but focused on climate related phenomena like sea level changes, droughts, and flooding. Closely related to climate resilience are considerations of sustainability, and to what level human intervention and strategies impacted the level of sustainability or vulnerability to climate changes. Such strategies include water management (discussed below), agricultural technologies and systems, and activities that affect deforestation. Therefore, when we reconstruct past environments and climate changes, we must ask to what degree human actions influenced those changes or lack of changes due to the creation of more stable and resilient systems.

While increasingly precise and advanced environmental reconstructions deliver excellent chronologies, sometimes that raw data can naively be interpreted as the mechanisms of mother nature to which human societies must adapt, rather than as a record of the wholesale results of human and environment interactions. Beyond deemphasizing the role of cultures and states in directing their own destinies, overarching environmental models often fail to contextualize the nuances of regional and micro-environmental differences and changes (Iannone, Prufer, et al. 2014). To avoid such pitfalls, I examine in detail the difference between and within regions and sites to refine and establish regional, site-specific, and even variable intrasite ecological differences and niches in order to evaluate the resilience, sustainability, and/or vulnerability of sites of a variety of levels and styles of social organization and environmental niches. Foremost in this study I propose to further our understanding of the Anthropocene and Mayacene by focusing on water resources and water management strategies of past environments and cultures.

2.3 Water and Water Management

In addition to potable water for human consumption, peoples of the past needed water for all manner of purposes. Agriculture and animal husbandry demand a considerable amount of clean water, as do cooking, washing, and bathing. In many Mesoamerican cultures, other practices that involve heavy water use include ceramic production, jade working, and lime production, but these and other activities likely did not necessitate potable water. The needed amount for all of these purposes can vary based on environment and climate, geology, type and strategy of agriculture, and style of cooking, amongst other factors. In all cases and places throughout history, water is of paramount importance.

Like the Chicxulub asteroid that catalyzed a mass extinction event 65.5 million years ago (Schulte et al. 2010) and still leaves its hydrological legacy on the Yucatán Peninsula today, most of the Earth's water is extraterrestrial in origin and indeed older than Earth itself (Cleeves et al. 2014). Though now abundant on our planet, the vast majority is saltwater, and the struggle to obtain clean fresh water as a precious commodity has diffused throughout the globe. Today we face global freshwater scarcity on an unprecedented scale (Mekonnen and Hoekstra 2016), partly due to climate change. This crisis is not merely environmental, nor one of overpopulation as neo-Malthusianism and ecofascism hold (see Bookchin 1988; Ehrlich 1968), but a crisis embroiled in societal logistics, economic systems, and political organization. By researching how past societies adapted, overcame, and/or failed in the face of water scarcity and climate change, we can learn from their triumphs and mistakes in order to alleviate the suffering of the contemporary and future inhabitants of the world (Redman 2005).

Water is one of the fundamental resources that shapes human practices and constructions. Yet, its fluid nature renders it difficult to study as a measurable unit, ecofact, or agent in the material record studied by archaeologists. In an essential paper published over a decade ago, Ingold's (2008) SPIDER lectures, "the fish in the river is able to swim ... because of the way it creates eddies and vortices in the water through the swishing of its tail and fins. But what sense would it make to say that the fish dances with water as it might with other fish in the shoal?" Water is not an object that acts, the arthropod presumes. Like air, it is material media through which living creatures move and interact, and if these agents are extracted from such material they would no longer be living. Water is more than just this neutral material media matrix meshwork, however. Its qualities, state of matter, abundance, distribution, and other features dictate just what sort of creatures can live within or near it, and how many. Therefore, we must cast aside hylomorphic thinking and instead realize that water can be studied through an archaeological lens as a *hyperfact* (Normark 2014).

We must recognize that cultural perceptions of water and water bodies differ across space and time, as they do for all phenomena. These perceptions are not only valid from a culturally relativistic standpoint, they also often have the ability to inform the more "rational" scientific western perspective of environmental processes. For example, the hydrologic cycle scenario that many of us learn in grade school focuses on evaporation from the ocean or other exposed water bodies in order to create clouds through condensation. The Maya cultural and cosmological perspective, however, focuses on clouds emerging from caves, an aspect of their cosmovision seen both in the distant past (Stone 1995; Taube 2010) and in contemporary populations (Vogt 1981). This helps us to consider aspects of the hydrologic cycle to which we might otherwise not pay much attention. Further examples and considerations of Maya perspectives, considerations, and relationships with water will be discussed in the culture history and cosmology chapters.

Early archaeological studies of settlement patterns and ecology focused primarily on rivers and shorelines (Coe and Flannery 1967; McIntire 1958; Phillips et al. 1951; Willey 1953). Settling near such water bodies helped facilitate travel and trade, often provided rich aquatic resources, and moreover served as the primary water supply for drinking (though not in the case of saltwater bodies, of course) and other human needs. Over centuries (or in some cases decades or even annually, as in the case of the Amazon and the Indus), however, river courses change, lakes dry up, and shorelines shift. This results in two main questions for archaeological inquiry into past settlements and ecosystems: 1) Were these environmental changes purely natural (non-anthropogenic) or were they helped along or even primarily catalyzed by human activity (anthropogenic), intentionally or not; and 2) How did those societies adapt to such changes in their environment? For both of these questions, a key element is the rapidity at which the environmental changes occurred. Another key factor is how ancient societies used and managed their water supplies. What were the demands placed by human societies upon water bodies and hydrologic systems, what were the requirements demanded of humans to access and use those water bodies and systems, and how did they affect one another?

Water management has been a topic that archaeologists have theorized for quite some time. The idea of water management as a catalyst for state formation and emergence dates back to Karl Marx. When discussing the origins of the Asiatic mode of production, he asserted that "one of the material bases of the power of the State over the small disconnected producing organisms in India, was the regulation of the water supply" (Marx 1887:365). Later, Karl August Wittfogel (1957, 1972) took up that torch to a more deterministic extreme, and famously argued for a "hydraulic societies" model in which irrigation and water management went hand in hand with state bureaucracy due to the need (in his estimation) for specialized bureaucratic oversight for advanced irrigation and flood control systems. However, just as agricultural development and intensification predates urbanism and state organization (Beach et al. 2009; Netting 1993; Wahl et al. 2013), so do water management technologies.

Scarborough (1991, 1998) has critiqued Wittfogel's model as a "top down" approach, and especially inaccurate in the case of the Classic Maya. State power can organize large-scale complex water management and other systems, but it often does so at the expense of small communities and of "organizational efficiency" (Scarborough 1991:124), as the state bureaucratic order controls, integrates, and restrains the already complex social organization that existed within communities before the rise of the state. Scarborough (1991:124) also notes that the "kind and degree of control used by early states differed markedly." In the material record, these differences are manifest through features of the state such as demarcated territorial borders and walls, but also by changes and continuity in community organization and practices reflected in the artifacts and architecture of small-scale farming/gardening and residential areas.

We must also keep in mind that in order for a state to keep control of a particular landscape and thus its water and other resources, it must be able to defend that land from outside incursions. Eric Wolf (1982:113) relates how warfare and the seizure of people and provisions have often served as a means to secure resources and as a mode of social reproduction in favor of industrial and commercial development. This becomes particularly important to consider when we examine the role of warfare in northern Mayab (Ambrosino 2007; Ambrosino et al. 2003; Freidel 1992a; Stanton and Brown 2003; Stanton and Gallareta Negrón 2001), especially as a possible response to scarcity during the major droughts in that region during the tenth century (Douglas et al. 2015; Iannone, Yaeger, et al. 2014), a longstanding debate on which I will deliberate later in this work.

Beyond the role of the state in water management, we should consider the strong influence of community approaches to water management strategies. Water bodies are monumentally important in forming and maintaining community identities, especially amongst the Maya, who often name places, lineages, kinship groups, and/or other communities after the waterhole around which they live and perform ceremonies which form these "water groups" (García-Zambrano 1994, 2007; Vogt 1976:99). Lansing (1987) famously detailed a similar role and significance of water temples in Bali, where water management was localized by relatively small communities - *subaks* - yet still homogenized and organized on a grand scale throughout Bali. Scarborough and Lucero (2010) highlight the importance of heterarchical relationships and cooperation inherent in the water management systems of the Maya and other peoples. Rather than a calculated consolidation of power, they envision early urbanism as a product of market and community cohesion. Rather than cosmology and ritual co-option by the elite toward avaricious ends (as I will argue), they propose that mythology and public ritual helped to manage and preserve water resources facing over-exploitation (Lucero 2003, 2006; Scarborough and Lucero 2010).

2.4 Communities, Cities, and States

To facilitate a theoretical approach of water management at various levels and types of social cohesion, this research analyzes communities of different sizes/scales. Given the importance of community size and composition, it is useful to unpack the concept of community. Yaeger and Canuto (2000:5) define a community as an "ever-emergent social institution that generates and is generated by suprahousehold interactions that are structured and synchronized by a set of places within a particular span of time," and it is with this working definition that I guide my spatial research. Put more simply and succinctly, communities *are* their shared practices and spaces. Though ever emergent and ever-changing, communities create distinct spatial patterning of the material record through their daily practices which allow archaeologists insight into the form, manner, and intensity of these practices through examination of the distribution of architecture and artifacts.

However, it is important that we do not conflate form with function, either of architecture or artifacts. For example, in their investigations of Sayil, Smyth and colleagues (1995) primarily utilized architecture, ceramics, and soil for their assessment of settlement patterns at the site. They considered these elements separately but also in relative comparison to one another. In doing so, they were able to ascertain that while some monumental architecture had similar forms, they may have had quite distinct functions in light of the variation in the amount and distribution of different ceramic vessel forms and assemblages. Therefore, with analysis and comparison of these multiple datasets we may better determine function and activities associated with distinct areas in the ancient past. This approach will be delved into further in Chapter 6.

Communities themselves can manifest in a variety of scales and forms. A community can be a relatively isolated village, a string of towns stretched along a river or road, a busy metropolis, or even an entire state or nation. Furthermore, communities can exist beyond spatially discreet units. There can be communities of class or socioeconomic status, of occupation, of political affiliation, or even of sports team fandoms, so each individual belongs to several communities at the same time.

Variability in communities can reveal societal strategies for water management and stability which transformed the landscape over time through continual feedback between anthropogenic alterations and influence on the landscape and non-anthropogenic climatic cycles and changes. Water features are an important part of this, as flooded lakes or rivers can disturb settlement, or human modifications to lakes can render them more susceptible to drought. Water management strategies also forge communities around such practices. Irrigation systems and terracing practices, for example, both organize spatial groups of communities of farmers, and homogenize the culture, practices, and norms of farming throughout those communities, forming an overarching supra-community of agriculture and water management practices.

Likewise, polities and cities both contain numerous small communities and themselves are large "imagined communities" (Alonso 1994; Anderson 1983), that is, communities that are socially constructed through shared perceptions of cultural symbols, myths, and histories, but that are constituted of people who have never met and do not know one another on a personal level. Benedict Anderson (1983) coined this term specifically for nation states of more recent centuries since the dawn of the printing press and mass communication, but I believe that even early states and kingdoms like those of Maya polities had a certain degree of this same sense of imagined community as collective subjects of an *ajaw* and thus common members of a sometimes vast domain and populace made up of places they did not necessarily go and people they could not possibly know all at once (Inomata 2006). However, they did sometimes gather in large ceremonies which helped foster a sense of community in lieu of mass communication, and in some cases these ceremonies took place at the banks of important water bodies, connecting the populace to these unifying life-giving water sources.

State power is embodied in symbols and legitimized through public displays, such as Geertz's (1980) "theatre state." For Inomata (2006:808), these public displays are prime movers for the inception of hierarchical organization due to the logistical requirements for large public spectacles. Large plazas and wide formal *sacbes* are the primary locales for such activity proposed by Inomata, but I will argue that large sinkholes and water bodies were also prominent areas for ritual public spectacle tied to efforts to shape community identities. Lucero (2006) considers the role of water management and the ritual invocation of rain and favorable seasonal conditions as primary to the role and rule of Maya elites through such performances. This practice of performance was not merely a top-down arrangement; lower classes were the active audience in community building and "became, whether willingly or unwillingly, accomplices in the creation and maintenance of the dominant regime" (Tsukamoto and Inomata 2014:6; cf. Joyce 2000).

As imagined communities, cities are large and complex, but defined more by social ties and interactions than by size or complexity alone. "The city may be looked on as a story, a pattern of relations between human groups, a production and distribution space, a field of physical force, a set of linked decisions, or an arena of conflict" (Lynch 2008:678). For archaeologists, cities present themselves primarily through type, size, density, and arrangement of architecture and other features such as roads, canals, and reservoirs. Settlement archaeology considers this variation and distribution of architecture and other features and how they interconnect and relate to the surrounding environment. These relationships underscore political and ideological processes, and form the cultural, economic, and political landscape of communities at every scale. Combined with chronological data, such relationships highlight community adaptations to environmental change. Furthermore, the control of water in cross-cultural contexts informs us of community structures and to what degree and manner they articulate with state structures.

Thus, this research also heavily concerns landscapes and waterscapes. Landscapes, in settlement ecology, are not only defined by the natural environment or even simply the human-environment relationship, but specifically that continuum defined by “a matrix of land-extensive and labor-intensive tactics and strategies” (Anschuetz et al. 2001:177). More specifically, landscape limnology research focuses on freshwater ecosystems (Soranno et al. 2010). For archaeology, waterscapes express both the geographic water conditions/systems and the “structural engineering of water features, the social and political relations among cooperating groups, and the cultural role of water” (Wyatt 2014:450–451). Water management and waterscapes are thus of vital importance to understand community organization, state formation, and other social, economic, and political processes.

Both large state water management and smaller community-level projects have influenced landscapes, environments, and climates at a regional scale in Mesoamerica and around the world for millennia. For instance, archaeologists (Fletcher 2009; Scarborough 2003) have noted the similarities between large Classic Maya cities and the Angkor complex of the Khmer, not only for their grand central temples and tropical climes, but also for their agrarian urbanism and large-scale water management networks that bound together suburban communities into sprawling cities. Conversely, the *subaks* of Bali constitute a localized community-oriented system of water management networks independent of the state, where rituals in “water temples” organize the timing and amount of water supplied to rice terraces as to “construct a complex, pulsed artificial ecosystem” (Lansing 1987:326). Though concentrated around local communities, ritual practices of the *subak* irrigation system facilitate and mediate shared water management practices through a shared cosmology and ideology to create a relatively homogenous yet complex social system throughout Bali (Lansing 2006). Further, Scarborough (2008) envisions both Maya and Bali past societies as primarily labortasking rather than technotasking, the latter of which involves marked centralization of resources and tends to speed up ecological precariousness. Labortasking instead slowed the rate of environmental alterations and allowed for a more flexible approach to water management strategies.

The study of Maya water management systems aids us in understanding the formation, integration, and collapse of political systems over time and space, and allows scholars to better analyze and compare such systems and changes in diverse regions of the world through the lens of regional climate changes throughout prehistory. Thus, this research must also confront theories surrounding nature and governmentality.

2.5 Nature, Culture, and The State

The above discussion leads us to question what we mean when we speak of governments, rulers, resistance, polities, and united peoples. The idea of the state is central to my research, as it seeks to understand the role of state organization in the resilience (or lack thereof) of cultures in the face of climate changes. Before I define and analyze the idea of the state itself, I would like to address the age-old nature vs. culture dichotomy as it weighs upon my research, especially as culture is intertwined with state/government influence. Jean-Jacques Rousseau's historical-dialectical view of society imparts how human nature is not a static nor genetic nor fundamental entity, but a "historical process associated with the emergence of human beings from nature through the creation of culture and their transformation of nature through social labor" (Patterson 2018:28).

It is difficult if not impossible to pluck apart singular entities of a *culture*, *state*, or *nature* in any meaningful way without consideration of the others. However, for the purposes of my research I must make distinctions between these ideas to make a case for each as a force that influences the next, especially in regard to climate change and water management practices. For this reason, I have and will continue to use and prefer the terms *anthropogenic* and *non-anthropogenic*, over *cultural* and *natural*, especially in regard to climate. These forces are bound together, and human activity can combine with extant geological, hydrological, meteorological forces to exacerbate, ameliorate, and/or support one another. Nevertheless, I believe meaningful claims can be made for the strength of one force over the other as catalyst and primary driver in respect to long-term climate changes (for better or worse), as will be detailed in later chapters.

Additionally, I acknowledge that the smaller communities I analyze are not wholly removed from the state, its apparatuses, and its power. In a region heavily dominated by polities (through most of the epochs I will be analyzing), even the far remote hinterland rural village or area is in some manner influenced by state power, intentionally or not. However, I believe qualitative distinctions can be addressed by the consideration of the entirety of the architectural layout and recovered material remains to distinguish the degree to which sites may tend toward greater levels of hierarchical management and/or the embodiment of state societies.

Antonio Gramsci (2011 [1930]) wrote of cultural hegemony, a crucial aspect toward maintaining the dominance of the ruling class over the proletariat by shaping and controlling the values, beliefs, norms, and worldview of society as the "common sense" or "natural" way of thinking, which in reality serve the interests of the ruling class. With this concept, Gramsci was responding to the rise of fascism in Italy (and his own imprisonment within that system), but it can also be applied to almost any state society that is interested in maintaining order. As long as individuals are allowed to feel a sense of purpose of some sort, the need for oppressive physical force should not be so great. Foucault (1978:95) framed the problem thusly: "Where there is power, there is resistance, and yet, or rather consequently, this resistance is never in a position of exteriority in relation to power."

Ubiquitous resistance within power relations yields continual changes in society. This is due in part to the fact that the political and economic struggles that we observe in large cultural systems are also manifest in personal and individual struggles. But what is personhood and an individual apart from their communities and networks of interaction which influence them? Eduardo Kohn (2013:75) posits that a self "does not stand outside the semiotic dynamic as 'Nature,' evolution, watchmaker, homuncular vital spirit, or (human) observer." Selfhood is the outcome of a process, and a process itself, just as communities and cultures are processes. Furthermore, there is no real meaningful distinction between an Othered “nature” and the self, individual humans, communities, and cultures. They all influence and are imbedded within their environments, and thus are a part of nature, not apart from it. In fact, ecological systems and communities have selfhood as well in this schema of interactions.

The fundamental question is one of power – the *Macht* which Weber (1968 [1921]) defined as the "probability that one actor within a social relationship will be in a position to carry out his own will despite resistance, regardless of the basis on which this probability rests." Our communities and cosmologies shape our existence but are vulnerable to power relations, and thus are open for utilization by the state as one method of control and normalization. Often the model of state normalization is co-opted in part from aspects of a more benign cosmological paradigm of the culture at large.

At the site of Chan, Belize, Cynthia Robin (2016) documents the humble household and farmstead cosmograms of the Maya cardinal directions and color schema, made from broken artifacts and river cobbles, and reminds us that their creators were "neither dopes nor dupes" of a dominant ideology, but critical thinking members of society that understood the origins and meanings of their cosmovision, even when co-opted by royals and elite power structures. It is clear that this cosmovision pre-dates the state and in no way originates from elite "high culture" but instead from the lowly farmers. Contrariwise, elites understood that their subjects were no simple dupes, and that their power depended on continued successes, especially with fundamental factors like proper water management and agriculture. Crises, both natural and anthropogenic, could therefore become opportunities for the elite, and might be exploited to turn the resulting chaos into a reminder for the need of power structures and normalizing influences.

Culture itself is a normalizing influence, used by power structures to ingrain appropriate behaviors within populations. This process is repeated and practiced until the formalization of procedure is seen through the end product similarities (Horkheimer and Adorno 2002 [1944]). Culture is ever-emergent, as are its constituent parts. "Like our thoughts and minds, birds and plants are emergent reals. Life-forms, as they represent and amplify the habits of the world, create new habits, and their interactions with other organisms create even more habits. Life, then, proliferates habits" (Kohn 2013:62). If our thoughts and minds are emergent reals, constantly being influenced by our culture and surroundings, culture may be seen as a standardizing stimulus which influences our behaviors, decisions, and actions.

The relations between culture, economic and political systems, and "natural" systems and environments are multi-directional, multifaceted, and manifold. "In a phrase, culture is the arena in which the ambiguities, antagonisms, and contradictions of everyday life are expressed, reproduced, and occasionally resolved" (Patterson 2009:105). This remains true even in consideration of the multifaceted identities and cultural group belongings of community members to a variety of communities and cultures, as earlier discussed. Therefore, with this arena of culture as background, my theoretical underpinnings must also address state formation, deformation, apparatuses, and power.

State formation and deformation processes have long been foci of archaeological and anthropological theory. State deformation processes are commonly couched in terms like *collapse*, *abandonment*, or *decline* of ancient sites and civilizations, and usually focus on external catalysts for such decline: e.g., natural disasters, military conquest, shifting trade routes, or introduced epidemic disease. Even internal resistance to the state is often seen as necessitated by other factors and pressures, be they population booms that stress resources, or environmental changes. Such forces may be the opportunity for political changes, rather than the catalysts themselves, and only result in significant alterations to the status quo if the people are unsatisfied and able to make the most of said opportunity.

2.6 States, Heterarchies, and Anarchies

During my first archaeological project in 2005, I naively presumed to have coined the term *anarchaeology*, being unfamiliar with the work of Carole Crumley and others. Nonetheless, my attraction to the ideas behind this existing term has been borne out by a review of the literature. The goals of anarchaeology are to acknowledge and observe non-state organization and/or anti-statist resistance, and to apply that knowledge to our current predicaments. Anarchaeology promotes an "ethical and moral stance from which to critique power and to seek non-authoritarian forms of past and present organizations" (Crumley 2017:22). It also recognizes and encourages diverse ideas surrounding heritage, knowledge, and authority, both in the past and projected into the future. Like anarchism in general, anarchaeology acknowledges that not all uses of state power are evil and corrupt, and likewise not all anarchic organizing is benevolent and utopic. The Kowloon

Walled City, for example, was a testament both to the ability and ingenuity of people to not only survive but thrive and organize in harsh conditions without state intervention, but also to the crime and harsh realities of guerilla capitalism which that brand of anarchic urbanism spawned. Kowloon also highlights the difficulty in observing such entities in the material archaeological record. A once towering compact city is now a government park which preserves the older historical foundations but seeks to minimize the memory of the problematic era.

What is the state, really? One of the more common definitions of the state is that of Weber's (1919:4) "Monopol legitimer physischer Gewaltsamkeit" or "monopoly of the legitimate use of force," though this idea was earlier published by Rudolf von Jhering (1872). Franz Oppenheimer further developed this premise, declaring that the state exists fundamentally as a social institution, initially generated by the domination of one group over another. "Teleologically, this dominion had no other purpose than the economic exploitation of the vanquished by the victors" (Oppenheimer 1926:15). Oppenheimer used the terms *economic means* and *political means* to distinguish between one's own labor or the equitable exchange thereof in the former, and robbery or exploitation of other's labor in the latter, noting that such is crime for the individual but legitimized normalcy for the state. The state is not merely or only a means of coopting economic power and exploiting labor, however.

For James C. Scott (1998), the state is the practice of social engineering gone awry, which seeks state-level goals. The term *state-level* itself is an unfortunate term embedded in our language which connotes a hierarchy where the state is a higher order of society and social structure, and smacks of unilineal evolution. As Žižek (2002:2) opined, "We feel free because we lack the very language to articulate our unfreedom." Scott conceptualized four core elements that characterize state endeavors: administrative order of nature and society, high-modernist ideology, authoritarian state with coercive power backed by looming threat of force, and a prostrate civil society that lacks the power, will, and/or capacity to put up resistance to such schemes (1998:4–5).

Philip Abrams (1988:58) took a similar practice theory of the state a step further, declaring that the "state is not the reality which stands behind the mask of political practice. It is itself the mask which prevents our seeing political practice as it is." Abrams divided the state into the state-system (or structure) and the state-idea, reified in the minds of its subjects but truly existing in no concrete tangible reality, which confounds attempts to dismantle it and to study it materially in the archaeological record (though not as difficult as its opposite; see Kowloon example, above). This notion of the state-idea is similar to that of ideology, which I will discuss further in the next section of this chapter, below.

Yet state-ideas *are* actually made real and tangible through the material culture that reflects those ideas. This is important, as this material culture is the only way in which we as archaeologists can hope to perceive them in the material record of past cultures and societies. Ana Alonso (1994:382) grounds the experience of the state not only in discourse but also in space and place, noting that "the nation is rendered real through a vast iconic structuring of 'public' social space." This can take the form of literal structuring, where formally localized spaces and edifices are transformed to better suit a larger homogenized domain, and “an objectified official history makes the presence of the state palpable in everyday life” (Alonso 1994:382).

In the case of the Classic Maya, stelae were the consummate material incarnations of the official histories of their respective polities. Along with grand public structures, plazas, and other monuments, stelae not only served as official histories and propaganda to promote royals as gods or absolute authorities, but also instilled a sense of pride and identity within the public associated with the state. These were materialized symbols of hegemonic strategies that served to “produce the idea of the state while concretizing the imagined community of the nation by articulating spatial, bodily and temporal matrixes through the everyday routines, rituals, and policies of the state system” (Alonso 1994:382).

This gets to the heart of the definition of the state and informs my own working definition. For myself, the state is a process of top-down order and organization that ignores, devalues, or suppresses the lives and wants of individuals and communities while promoting and privileging a regimented structure which supports smooth economic transactions and ease of political administration and domination. The state is the amalgamation of these ordered forms of legitimacy through laws and power that hold up those norms and their structure as more important than the lives of the human beings it purports to rule. On the one hand, the state exists as a phantom in the minds of its subjects who breathe life into it and give it power with their belief, complicity, and/or support. On the other hand, the state becomes reified and concrete through the material manifestation of its administration in the forms of monumental architecture, city layouts, centralized elite-controlled reservoirs, and/or other public works that serve the interests of the ruling class. The state apparatus also regulates and regiments the environment and the landscape, in order to control it, often without the foresight or forethought of sustainability or consideration of altered ecologies and ecosystems. It commodifies all it can, not only the products of labor but natural resources and human beings themselves.

Just as the state is a process of centralizing control and legitimizing power, so too is there an opposing process of resistance and alternative forms of order. Yet sometimes this resistance can become a recursive cycle which further legitimizes state control and power. "Heterarchies of power – coalitions, federations, leagues, associations, communities – are just as important to the functioning of many states as they are to more egalitarian groups (bands and tribes)" (Crumley 2003:137). This is an encouraging notion, and on one hand we can rejoice in the knowledge that heterarchical forms of power exist both within and beyond state societies. On the other hand, as long as alternative forms of order are content existing within an encapsulated state, they are an ineffective resistance that instead leads to more ingrained and indoctrinated state control. Though often helpful in the short term, these alternative forms are also often coopted by the state to cement authority.

The trend of analyzing cities, states, and political formations not as static entities but as fluid dynamic interactions is perhaps best modeled through a network paradigm. The network approach "calls attention to how power contests are waged close to the ground by self-reflexive agents who co-operate within wider webs to mobilize material and conceptual resources in support of common political projects" (Schortman and

Ashmore 2012:1). Networks within networks create the web of interaction that results in not only state but community power. Analyses of the origins of power, hierarchy, and hegemony allow us to question what we mean by power, levels of power or the attempted balance of power, and power relationships between and within networks of interaction.

Alonso (1994) also questions how the identities of people and places (referring to the built environment) are made and remade in the midst of constant change in these networks. She refers to modern increases in homogeneity, global capitalism, and fragmentation of space as nations are carved up and more, but this also occurred in other ways in the ancient past. How do we see this in the archaeological material record? Much of the more ephemeral nature of the state-idea is couched in terminology, discourse for which the language may or may not have written records or surviving descendant communities that speak a similar language. Yet discursive practices result in naming features of the natural world in a manner that encourages the legitimization of political control and dominion over such natural features (e.g., kingswood, or royal forest).

Language also reflects ideas of the family or kinship onto the state, and vice versa. Kinship tropes, such as the use of familial language to describe the relationship between the state and its citizens, can serve to legitimize and naturalize existing power structures and hierarchies by imbuing them with moral and emotional significance (Alonso 1994:385). We see this reflected in words like motherland and fatherland, and similar terms exist in many other languages. Through this modus, the humble hierarchies of kinship groups become a learning model of submission to overarching state hierarchies, oppression, and exploitation. Not only kinship terms and relationships, but also all manner of cultural symbols and meanings are actively involved in constructing, shaping, and maintaining social structures, including the state (Sahlins 1993). Members of the ruling class also coopt history itself through discourse, creating a narrative of the past that legitimizes state power and the dominant ideology. “Pasts that cannot be incorporated are privatized and particularized, consigned to the margins of the national and denied a fully public voice” (Alonso 1994:389).

2.7 Identity, Ideology, and Materialization

Creating and remaking identity in the midst of change, both on an individual level and on a state level, leads us to ideas surrounding *ideology*, an additional aspect of the state for which this research demands a working definition as well. For some, ideology is more of a religious or cosmological worldview, whereas for others it takes a more political character. Demarest (1992) takes the former approach to ideology, while most of the contributors to his co-edited volume on the subject take the latter approach, as do I. Freidel and Sabloff (1984:183) define ideology as “the body of articulated sanctions promoting integrated and coordinated behavior in society.” Further, they highlight its independence from religious expression and symbols in the Maya region following the “collapse” of the Classic period, entering into what they still then referred to as the Decadent period, but better known now as the Postclassic.

During the Classic Maya period, however, Freidel (1992b) conceives of Maya ideology specifically as largely shamanic, yet this religious base is politicized for him through shaman kings, with royal rituals taking a shamanic form. Thus, he claims that monumental architecture was built with voluntary labor by commoners who wanted to contribute to these powerful ritual places. Seen another way, especially in regard to water management, "water and kingship differentiated people and settlement through various sorting and selecting mechanisms" (Normark 2019:134). Such selecting mechanisms were water rituals, "machines" in Deleuzian terms (Bryant 2014), which bound and entrained the life of the ruler to the hydrological cycle. Water rituals were firmly embedded in the ideology of the elite, underscoring the difficulty of effective resistance to state power in the face of such overwhelming cultural hegemony. After all, if the *ajaw* is responsible for the rains and life-giving water, it would be counterproductive and dangerous to one's life to oppose him, not only by insinuated threat of force but for fear of disturbing the natural cycle of water.

Nonetheless, some non-elites indeed had means of resistance through other avenues. Payson Sheets (2000) places the economic prerogative with the commoners residing at El Cerén. Though the choices between marketplaces he describes may smack of the illusion of choice in capitalism, it is an indication at least of competing control over economic domination of crafts and resources by competing polities. El Cerén also teaches us that individual households had multiple polychrome ceramic vessels, at least one jade celt, and other goods obtained through long-distance trade, revealing that some valuables that we formerly envisioned as elite possessions were (at least in some cases) accessed quite commonly by commoners.

Recent research (Ford et al. 2022) on cacao chemical residues on ceramics confirms that what was once thought as a kingly beverage reserved for elites and ritual feasts was actually far more common as well, enjoyed by the lower classes of urban areas and by farmers and inhabitants of hinterland rural areas. Commoners could perform their own religious rituals, and some may have been able to read and write, making the job of the state to lure in subjects all the more difficult. This perhaps better explains the intense competition between Maya polities and the drive to create such grandiose structures and monuments to reinforce state ideology. In fact, it may place such commoners outside of the Eric Wolf's (1969:xiv) definition of "peasant" and instead closer to "rural dwellers who live outside the confines of [a superordinate state]."

Ideology can also be connected to our previous discussion of language and the naming of natural features to legitimize and in some cases materialize state power. Emily Umberger (2002:196) describes the hegemonic process of imperial inscriptions of the Aztec landscape in the guise of sacralization of territories, but it was also a political act, and the elite rulers were those most invested in imbuing this empire ideology into the landscape to help affirm their rule and legitimacy.

2.8 Urbanism and Urban Processes

Often, the materialization and distribution center for ideology is in urban centers. Though ritual violence within urban ideologies were "ideally the exclusive prerogative of the high elite (as evident among the Moche and Maya), such ideologies were still intended to engage lesser-elite and lower-class segments of the population (even if at a distance)" (Swenson 2003:283). However, just as we must be careful in assuming that the state emerges from or with large public spectacle or monumental architecture, so too must we hazard against conflating the rise of the state with the rise of cities and urban development. Though they often did arise at the same or similar time frames in distinctive regions, in some cases even as a “city-state,” they do not necessarily go hand in hand in all cases everywhere.

The Neolithic settlement of Çatalhöyük, for example, was fairly egalitarian, though considered a proto-city at best, or defying formfitting definitions of urbanism and traditional categorizations of a city altogether (Düring 2007). Mohenjo-daro and other Indus Valley ancient cities stand more firmly within urban category territory, but likewise appear to have been classless (Green 2021). Nevertheless, a rise in population density took place in many other areas – after initial constraints on village size – not only through technological and structural advancements in agriculture, but also through social changes like the broadening of household size to incorporate larger lineages (which does not necessarily coincide with agriculture, as many hunter-gatherer groups had expansive households, e.g. the Kwakiutl). In many cases, the resulting urban centers did indeed lead to state societies.

Considering early urbanization is important to ideas of water management because most of the world's earliest cities spawned near water sources, mainly rivers. Mohenjo-daro mentioned above along the Indus was joined by Harappa and several other cities. Eridu, Ur, and others were nestled along the Euphrates and Tigris. Memphis and more Egyptian cities flourished aside the Nile. Tiwanaku grew near the shores of Lake Titicaca. Most early riverine cities practiced flood recession agriculture (aka flood retreat or *décrue* farming), as did some around lakes as we will see with Cobá (though Cobá is not in contention for earliest cities), but more advanced irrigation methods began early on. Indus Valley cities engineered reservoirs as early as 3000BC and sophisticated canal irrigation systems by 2600BC (Rodda and Ubertini 2004). Choga Mami in modern day Iraq boasted the earliest known irrigation canals in the sixth millennium BC (Oates 1969), which allowed it to be flourish further away from the Gangir River that supplied the canals.

These distinctions are important, as early cities and proto-cities that practiced flood recession farming did not require much in the way of central management, let alone state-level organization. As Graeber and Wengrow (2021:235) point out, *décrue* farming has an "inbuilt resistance to the enclosure or management of land. Any given parcel of territory might be fertile one year, and then either flooded or dried out the next, so there is little incentive for long-term ownership or enclosure of fixed plots." When the landscape is dynamic, there is no reason to carve a piece out to defend and/or invest time, labor, or landesque capital. Just the opposite in fact, as "flood-retreat farming was practically oriented towards the collective holding of land, or at least flexible systems of field reallocation" (Graeber and Wengrow 2021:235). In other words, flood recession agriculture was more hospitable toward Bookchin's (1982) ecology of freedom. This is not to say that irrigation or reservoir construction must inevitably result in state societies, but they do more easily lend themselves toward that path. The main takeaway is that many early settlements (including cities) that developed agriculture and greater population density did not necessarily form states, nor have much motivation to do so, despite the prevailing wisdom that the defense of settled agricultural lands lead to private property and from there eventually to early "civilizations" or states.

How did cities form and what impact did these formations have on social organization? Group rituals such as feasting, or even laborious communal tasks like monumental construction, served to connect basal units through cooperation and draw them into the larger growing community (Jennings and Earle 2016:476). However, the eventual rise and development of cities was not a strategy of resistance to state political structure or overarching power, as Jennings and Earle seem to suggest, because the state did not yet exist to resist. The archaeological material record at Tiwanaku used to distinguish these early relations by Jennings and Earle (2016:479) is also dubious, when they assert that “compartmentalization into compounds would have eased tension in the growing community.” Why? Could it not alternatively be interpreted as an indication of tension itself? It appears that they are describing the process of a bourgeoning city slowly installing greater measures of overarching state control and power, rather than resistance to it.

Perhaps it is better to conceive of the rise of urbanism in the words of Arthur Joyce, who seeks to move away from top-down structuralist paradigms and the reification of cities as static entities.

> Rather than integrated and coherent, societies are fragmented and contested to varying degrees such that there is never complete closure to any system of social relations. Practices and the cultural and material conditions that constitute social formations such as those that characterize different urban landscapes are always negotiations among differently positioned actors—socially embedded individuals and groups—distinguished by varying identities, interests, emotions, knowledge, outlooks, and dispositions. (Joyce 2009:192)

In other words, it is not merely (or at all, in some cases) state organization that determines city development and practices, but rather the combined interactions of all of the agents that exist within the city and perform their daily activities, like de Certeau's

(1984) walkers. Such city walkers can maintain and perpetuate state ideology with their quotidian practices, or they might threaten to upset and depose the same.

Alternatively, there might be an absence of state entirely, through a city forming without one in the first place or having toppled a former regime. This toppling could be achieved quite literally in these cities on material forms of stelae and other monuments, and/or of public architecture. “By the end of the Classic period, people throughout Oaxaca may have increasingly penetrated ruling ideologies such that Mixtecs, Zapotecs, and Chatinos, like their Maya contemporaries, experienced a crisis of faith” (Joyce 2009:193–194). Therefore, we must be aware that architecture, monumental or otherwise, along with artifacts, are not only a reflection of their creation and intended use and meaning, but also of their perception by others and the result of negotiations, contestations, and contradictions among different social segments. We must also be careful of attributing cause and effect, as the practice of creation of the accoutrements of the state coincides with the rise and constant recreation/process of the state, not as a result of it. “In monuments, we see not the consequences of political actions to legitimize centralized authority but these formations in the process of becoming” (Pauketat 2000:123).

Joyce also relates one of my favorite indicators of such a crisis of faith from the coast of Oaxaca at the site of Rio Viejo where a carved monument portraying a ruler was used as a metate and later as a foundation of a commoner house. Archaeological research must investigate the networks of complex human interactions and distinctions through the material record, rather than view artifacts and architecture as markers of a static city, a distinct and coherent political formation, or a personified state after the same fashion. These social distinctions were "instantiated in daily practice and recursively implicated in the material world of residences, ceremonial centers, exotic goods, crops, roads, etc." (Joyce 2009:195). Joyce also emphasizes the need to theorize how people in urban centers responded and adapted to catastrophic events, whether cultural (warfare) or natural (climate change), and how that influenced the trajectory and character not only of the city itself but as a network of individuals that make up the city. "Cities and polities do not respond as a unit to problems such as these" (Joyce 2009:195). Climate change, be it drought or flood, is not only an environmental crisis but also becomes a social problem.

When things fell apart for Classic Maya cities and royal rule, the social crises of reorganizing masses of people in different social orders did not prevent the cosmology and ideology surrounding water from continuing in different but similar forms. Most of those ideas predated the dynasties and did not require the grand spectacle of wealth and power in order to continue when they ended. Here the lingo of Deleuze and Guattari helps us envision how Maya communities of farmers and other laborers, "without kingship as an apparatus of capture ... *deterritorialised* and *reterritorialised* elsewhere as new hydrosocial becomings. Hence, the 'Maya collapse' involved the disappearance of some machines, but not of the Maya world" (Normark 2019:135 emphasis in original).

2.9 Political Landscapes, Waterscapes, and Settlement Patterns

What are landscapes through an archaeological lens? Knapp and Ashmore (1999:1) define landscape minimally as "the backdrop against which archaeological remains are plotted," but go on to discuss the economic, political, and social aspects of landscapes along with ideational landscapes of memory, of identity, of social order, and as transformation. In the following discussion, I will focus primarily on the political implications of the archaeological study of the settlement of landscapes and waterscapes.

As I have mentioned, cases where urbanism and monumental architecture predate the state may actually give rise to state power rather than the other way around. Adam T. Smith (2003:5) is concerned with these analyses and "ancient political formations in which authority was predicated on radical social inequality, legitimated in reference to enduring representations of civil community." Smith sees landscape as a "broad canvas of space and place" (Smith 2003:11) to which we apply meanings and representations, whether built or natural. Discussing the landscape of political expression and function is literally grounding what can otherwise be a theoretical endeavor removed from reality and devoid of context. "To leave the political unmoored from the landscape, to allow it to float across society and culture as a conceptual ghost ship simultaneously anywhere and nowhere, is to obscure the practical relations of authority that constitute the civil sphere" (Smith 2003:16). Some of the earliest recordings in history from Mesopotamia, including the opening of the Epic of Gilgamesh, are obsessed with evaluations and descriptions of built structures, often in the form of a boasting king. This Ozymandian boasting is not unique to the ancient world; it is recognized today in the national pride tied to national monuments, a pride that is heavily promoted by the state. Contrariwise, resistance is witnessed in the tearing down of monuments and statues of historical figures that represent ideologies whose time has passed.

Even when we do find compelling evidence for detailed political operations in the ancient past, we must keep a sense of the temporal and spatial relations of those operations. "In attending to the production and reproduction of authority in space and over time, politics begin to emerge within a set of intertwined relationships" (Smith 2003:110). When one asks, for example, what was the political nature of the ancient Maya, we must recognize that it is highly variable across the Maya region with its equally variable landscape, and throughout its storied history. The State may be everywhere and nowhere, but a state has a limit of influence and boundaries, however hard to define or hazy. "Landscapes are produced in many different spheres of authority … as a result, the landscape emerges as a palimpsest of relations of authority" (Smith 2003:110). This is a difficult but important message to keep in mind when characterizing the political paradigm of the past.

The regional state vs city-state models of Classic Maya geopolitical organization deliberated over by Smith may fall prey to a lack of consideration of the changing political nature over space and time discussed above. Maps on the topic offer an idealized snapshot of a proposed political reality with little room for nuance. Heavily influential states were unquestionably a reality of the Classic Maya region, but their rise and fall, strength, immediate competitors, resources, and fortunes changed over time. Surely the truth lies somewhere in between, with weaker but relatively independent city-states sharing the same "Mundo Maya" as encapsulated sites paying tribute to a regional powerful polity. In short, it was likely a big, beautiful mess. Scattered about this mess were stelae and other monuments dedicated to reifying a political ideology couched within a cosmological landscape of the imagination. Combined with the site planning itself, they often relate the settlement as a grounded central axis of creation and describe relations to other settlements. The debate arises in picking apart how accurately these carvings and placements describe real historical interactions versus prideful propaganda to help legitimize leaders. In essence, the cosmological centering of the settlement is a declaration of ownership by the divine rulers over this most holy of locations, a way to order the wild mess (both environmental and political) and assert mastery over their space. In the same moment, they are claiming history, first rights, and thus political power and legitimacy. Importantly, water bodies were often a part of these claims and connected with local identity, a phenomenon I discuss further in the following chapter.

Yet here once again we risk losing sight of the individual within these landscapes. Even large state formations like Monte Alban can have as much to do with individual agency and practice as overriding notions of causal economic, environmental, and/or political systems. These are not individual actors removed from their cultural operating system, however. They respond to and help form the culture in which they are embedded, to varying degrees. In the case of Monte Alban, that takes the form of what Joyce (2000) calls a "sacred covenant." The builders and site planners of Monte Alban used and transformed that covenant in their alignment of structures and plazas with cosmological paradigms, such as northern aspects of sky and rain and southern aspects of earth and warfare, marking Monte Alban as a "mountain of creation" (Joyce 2000:81).

Joyce considers sacrifice and ritual violence as a proxy for actual warfare, allowing commoners and others to join the covenant without direct violent intervention, for which they were rewarded with membership in the glorious state. This is not to say the leaders of Monte Alban never waged war. From its earliest inception over 2,450 years ago, they campaigned against Tilcajete for centuries until it was finally subjugated, and they continued to use military force for many years to come (Flannery and Marcus 2003). However, they won over more allies and subjects with luxury goods than it did with military might. Spare the rod, spoil the peasants. This sees an agency of commoners on a regional scale, rather than regional change as a result of elite agency only. Common folk may influence and are influenced by establishment of this “new covenant” and adapt to changing social networks, trade and distribution networks, bringing other communities into the fold to procure agricultural and other resources. Without direct subjugation through violent warfare, there must be some willingness to participate in sacred spaces.

The arrangement and distribution of structures can be as telling as their imposition on the landscape itself. Settlement patterns regularly reveal the social structures and practices which created them, and frequently exhibit a diversity of social and political organization throughout the Maya region. For example, research that compares the layouts of various sites can uncover alliances, cultural origins, and political state and elite organization strategies. Lohse (2004) investigates the site of Dos Hombres and analyzes the variation in commoner settlement patterns, identifying two categories of communities. The “corporate group pattern” (Lohse 2004:130) presents a hierarchical distribution of households and plaza groups wherein more elaborate architecture (indicating higher status) is built in areas of poorer soil. In contrast, denser settlement amongst more highly productive agricultural zones with a lack of easily ranked structures (by size or quality) typifies the "micro-community pattern," indicative of a less ranked society despite the greater propensity toward boundary walls. The absence of a distinct settlement hierarchy suggests "a cooperative, communally based decision-making structure" (Lohse 2004:134), observed in the Formative as possibly a more heterarchical political organization.

Of course, these settlement patterns change through time, creating a temporal dimension to landscapes as well. In the opening of *The Eighteenth Brumaire of Louis Bonaparte*, Karl Marx (1979:97 [1852]) famously professed:

> Men make their own history, but they do not make it as they please; they do not make it under self-selected circumstances, but under circumstances existing already, given and transmitted from the past. The tradition of all dead generations weighs like a nightmare on the brains of the living.

Could we not say the same thing about the surroundings, landscape, and environment of humankind? Land has a history itself, and though we build and shape the landscape with our buildings and public works, the natural (and previously built) landscape influences us as much if not far greater than we influence it. "As individuals express their life, so they are. What they are, therefore, coincides with their production, both with what they produce and with how they produce" (Marx and Engels 1970:42 [1846]). Perhaps the foremost means of production is the land itself, especially in pre-industrial societies, as it provides the means to grow food, as well as other raw materials. Waterscapes likewise provide aquatic resources, ease of travel, and of course vital water itself.

Through this materialist lens, Crumley (1994:5–6) defines landscape as "the material manifestation of the relation between humans and the environment" and historical ecology as "the study of past ecosystems by charting the change in landscapes over time." Historical and regional contexts are key. Where these contingencies and considerations go missing, there are serious shortcomings and failures to characterize the true nature of the subject at hand. Crumley (2017:26) again phrases it best:

> To re-envision an equitable future for humankind, there must be a means to conceptualize and evaluate shifts and trade-offs between exclusive and inclusive power relations in diverse contexts and at every spatial scale, and to assess their implications for society and their suitability for the future. Here broad theory deserts us: such work must be done in specific places and conditions, and it will ground us.

For this reason, I have often used examples throughout this chapter - either from my region of study or other projects and case studies - to ground theoretical contemplations in the real world, and to help target them in ways that can help contemporary society beyond simply adding to our understanding of history and trivia.

After all, we must not forget the land, the water, the environment, the world where we play out these roles. The environment is not merely an external thing to be preserved for its own sake, but an active living arena and relationship between humanity and all materiality. To paraphrase Žižek (2022), what is the ecological crisis if not a new form of proletarianization? Deforestation and climate change most immediately impact indigenous peoples living more directly off the land. Yet, though the consumption of a Western city dweller may be many orders removed from that direct land and water relationship, it still buttresses all of those consumed products, and thus the material existence of the urban as well. In the shadow of global climate calamities, we are all of us deprived of the natural substance of our existence.

2.10 Connections

To conclude, the material archaeological record is rife with evidence and examples of human social organization (including water management and urbanism) without state intervention, and of resistance to state power, but also of course with strong examples of state power and authority throughout much of prehistory. We must continue to be vigilant to delineate the difference and completely theorize how the rises and falls of states are yet another historically contingent aspect of the archaeological record. It is difficult if not impossible to create a list of criteria for what equals a state in all cases and all places. Just like cities, civilizations, or other such categories, not all states had writing, metallurgy, grid-patterned cities, and/or the wheel; meanwhile, some non-state communities did have many of these things. If we are careful in our work, we can learn not to privilege states and instead to recognize organization somewhat removed from such a presentist lens. This may be observed in a variety of ways, from iconography to trade goods to settlement pattern studies.

Likewise, we must consider a number of factors – spatial, temporal, and otherwise – when delineating sites and settlements as polities, "hinterland" areas, cities, rural communities, or other labels with social and political distinctions. Then we may consider these differences in light of various historical changes, climate changes, ecological zones and micro-environmental niches, agricultural technologies, water management strategies, and socio-political organization in specific regions that will ground our theory and our work. In the forthcoming chapters, we keep in mind these ideas while we apply them to specific instances of water management in ancient Mesoamerica.

Chapter 3 Maya Cosmology and Philosophy of Waterscapes

3.1 Introduction

The Maya venerate particular features of the landscape and waterscape, especially *áaktun* (caves) and *cenotes* (Clendinnen 1980; Freidel et al. 1993; Palka 2014). Like mountains and other natural features, caves are central to Maya religion, cosmology, and ideology, as dwelling places of powerful supernatural beings and ancestors whose breath bring forth winds and rains (Taube 2010). These cavities in the topography were often sanctified; liminal spaces perceived as gateways between the terrestrial world of the living and Xibalba (e.g., Stone 1995), the Maya underworld of the dead and home to fearsome deities. Visiting such places was to be in the presence of such entities, hence they were witness to all manner of rituals, including those involving votive offerings, sacrificial offerings, and/or supplication for protection (Re Cruz 1996), rains or good weather, fertility (Redfield and Villa Rojas 1934), success in hunting (Brown and Emery 2008), or other blessings.

Caves and *cenotes* especially were used to petition rain from Cháak, god of water, rain, and storms (e.g., Brady 2010; Prufer 2002), a paradigm drawing from very early Mesoamerican beliefs, for example Olmec offerings at the spring of El Manatí (Ortiz and Rodríguez 1994). In certain ceremonies, ritual offerings were thrown into a *cenote* not only to bring the correct amount of rain, but also to "propitiate the winds" (Redfield 1941:119). Perhaps the best examples of such offerings were recovered from the Sacred Cenote of Chichén Itzá, in the form of ornate ceramics, jade, intricately worked gold, skeletal material, and other artifacts (Tozzer 1957). The Maya also constructed a cultural environment that transformed their landscape, in an attempt to recreate and idealize aspects of the natural geography to cosmologically center the polity or community (Hutson and Welch 2014; Vogt 1981). Many of these recreations and their natural counterparts – pyramids for mountains, tombs for caves, reservoirs for lakes – also became sacred spaces and centers of ritual (García-Zambrano 2007).

Building from these concepts, this chapter will further examine the importance of caves, *cenotes*, and other water bodies for the culture, religion, cosmology, and ideology of the Maya. Addressing these issues will contextualize the roles of water in broader Maya society, and thus help with the understanding of water management and environmental relationships.

3.2 Maya Cosmovision and Linguistic Categories

First, we must understand something of Maya perceptions of the landscape and their place within it. In the previous chapter I discussed the false dichotomy of nature vs culture in general, primarily from a Western perspective. Not only is this particular nature/culture dichotomy flawed or non-existent in the Maya perspective, but the very concept of opposing pairs also has a different perception in the Yukatek Maya language (*t'aan*) and thought (*tuukul*). The cosmos is a *jícara* (*luuch*) split in half to form two bowls, with the *ka'an* (sky/heavens) above, the *metnal* (underworld) below, and the *yóok'ol kaab* (terrestrial world) in the middle.

This bipartite *luuch* also represents all complimentary pairs (as opposed to opposites) as distinguished by language and thought - life and death, night and day, wet and dry, etc. - not unlike the concept of yin and yang. There is a deep understanding that one of a pair cannot exist without the other, and that they each contain a piece of the other and are two sides of the same coin, to use a Western expression. Such a notion is known as *nuup*, one of several subject-specific "to close" verbs, in this case referencing the closing and bringing together of the two halves of the *luuch*, and, by metaphorical extension, all complimentary pairs. To further emphasize how the Yukatek Maya experience these antonym pairs as complementary rather than opposed, there are several fundamental ideas that share the same word as homonyms for what most Westerners would consider opposites: *kaxan* means both to search and to find, *ts'aak* means medicine and poison/venom, and *yaaj* means pain and love.

Accordingly, the Yukatek Maya linguistic categories of nature and culture carry quite divergent meanings from their English counterparts. Culture is *miaatsil* in Yukatek; the word has strong connotations of wisdom and knowledge, which are of course culturally learned, but does not carry the associations of class and division from the "natural world" as it does in some English contexts. The closest term to "nature" in the sense of a non-domestic area in Yukatek is *k'áax*, but *k'áax* more specifically means the forest or wilds where plants and animals are found and can be hunted or gathered. Large water bodies (including the ocean), deserts, caves, and other such "natural" landscapes and features would not be considered *k'áax*. The *k'áax* is an important but potentially dangerous place to the Maya. Local legends tell of encounters with supernatural beings of the forest like *alux* (similar to fairies), the Xtabay (similar to La Llorona), and the Che' Wíinik (forest giant), which can have frightening or benevolent results in various stories. The wilds can be domesticated for *kool* (milpas), *naj* (houses), or entire *kaajal* (towns) through centering the space in ritual acts of creation (discussed below, see also Stanton and Taube 2024; Taube 2003a).

Caves are associated with an idea found throughout Mesoamerica and beyond of a primordial locus of genesis, from which emerged the first peoples (Furst 1978; Heyden 1981; Recinos 1950; Taube 1986, 1993). Such stories and the languages in which they are told provide us with linguistic data to better understand the nuances in the relationship of the Maya to their landscape. Caves are rendered in Yukatek Mayan as *áaktun*, *joltun* (usually for smaller cavities), or *ch'e'en* (more generic). *Ch'e'en* may refer to any hole in the earth, but usually refers to a well, spring, or cave with water, which noticeably overlaps with *ts'ono'ot*, or *cenote*. Generally, a *cenote* has abundant water clearly visible from the surface, while an *áaktun* contains a dark zone, and may or may not contain a significant source of water.

The word *áaktun* is composed of *áak* (turtle shell) and *tun* (stone), though *áak* can also gloss as "structure" in some contexts as turtle shells represent roofs (Carrasco 2015). It is also found in terms such as *k'ab áak* (crossbeam) and *nokak* (vaulted or stone house). While a Western mind might tend to conceptualize turtle shells as hollow objects, the Maya view them as enclosed spaces.

Such a distinction is significant, because turtles and their shells are integrated into much of Maya cosmology, as representations of the earth/world (Taube 1988), as the vessel of the emergence of the maize deity and creation (Taube 1983), and as conceptions of the cyclical calendar (Taube 1988). Many turtles - including the most common mud turtle in the Yucatán, *Kinosternon creaseri* - have 13 primary scutes on their shells (5 vertebral and 8 costal), a number of great cosmological and calendrical significance to the Maya. They also typically grow 25 marginal scutes along the edge of their carapace, but 5 of these (2 supracaudal, 1 nuchal, and the 2 first marginals on either side of the nuchal) may be considered abnormal, resulting in the 20 vigesimal base of Maya numerics with an "extra" 5, reminiscent of the leftover five days of the shortened month of Uayeb at the end of each solar *ja'ab*. These enclosed *áak* turtle shell spaces include caves, *cenotes*, “milpas (enclosed by the walls of the forest), villages, which were ‘human’ spaces in the forest, houses, temples, and (in time), churches” (Clendinnen 1980:381). *Áak* is not the only term to carry a broad meaning. As mentioned above, *ch’e'en* means well or water cave, but is sometimes used generally to refer to the center of town or can be associated with the town itself (Tokovinine 2013), while *múul* and *wiits* (or *witz*) can mean hill/mountain or pyramid.

Further linguistic landscape and soil categories are discussed in Chapter 4, but the few terms above will be helpful going forward in this discussion of the cosmological and ritual importance of water bodies and caves. Variations in these waterscape and landscape features influenced how the Maya perceived and interacted with them, and how they planned settlement around or near them.

3.3 Caves and Water Bodies in Settlement Planning

Maya city planning and ekistics were closely related to and intertwined with water bodies and caves, not only for water management purposes but also for cosmological significance. The renowned central Mexican site of Teotihuacan is remarkable not least of all for its picturesque grid system, which, along with its massive pyramids, was laid out early in its history. This layout included artificial rivers running through the city by diverting the Rio San Lorenzo and Rio San Juan, as well as a sunken plaza in front of the Temple of the Feathered Serpent which would have flooded seasonally to create a reflecting pool (Pasztory 1997:73–138). Far to the east in the Maya region we find a single city with a grid plan before 500BC (Pugh and Rice 2017), predating urban Teotihuacan by several centuries. This early site, called Nixtun Ch'ich', was also much smaller than Teotihuacan, and was nestled in a peninsula along the shores of Lake Petén Itzá, which fulfilled their water requirements.

The grid system of Nixtun Ch'ich' appears not to have caught on with other Maya sites, as it is the only known example of such in the region. Most Maya cities are instead composed of a core area or several core areas of capacious plaza groups with monumental architecture, surrounded by clusters of smaller plaza groups and other dispersed structures. While Maya urban centers may appear more "organic" or spontaneous in their ekistic layouts due to multiple construction phases over time, they were still skillfully planned with rhyme and reason other than the grid plan. This civic planning often reflected Maya ideology and cosmology in a quadripartite plan observed within architectural plaza groups and site boundaries in general (Ashmore 1991; Ashmore and Sabloff 2002). Such reflections also stare back at us when we imagine the still pools of grand reservoirs or canals of the ancient Maya, themselves mirroring tranquil lakes and *cenotes*.

The central importance of *cenotes* and caves is attested by the construction of many settlements large and small throughout Maya history around *cenotes* and caves, often with important monumental architecture alongside or even on top of them in some cases. The layout of the contemporary village of Chan K'om is an ideal illustration of a common phenomenon in Maya *kaajal* (towns) of the Yucatán. There the center of the village is positioned around a *cenote* from whence it derives its name, translated "little kettle" from Yukatek Maya (Re Cruz 1996; Redfield and Villa Rojas 1934). Certainly, this arrangement is partially functional, logistical, and social, providing a central well for villagers to congregate as they draw their daily water, and perhaps wash clothes, swim, or bathe.

Yet, this *cenote*-centering also recreates the cosmological notion of the navel of the earth, the *tuuch lu'um*, *chúumuk lu'um*, or *chúumuk yóok'ol kaab*, which connects the heavens, the terrestrial realm, and the underworld through the axis mundi, represented as a cosmic umbilical cord or *kuxan sum*. Older generations of the Maya of Yucatán recount that the *kuxan sum* was cut by the conquistadors but rests dormant under the great ballcourt of Chichén Itzá, waiting for the day the Maya rule once more to emerge from the Sacred Cenote Xtoloc to reconnect the cosmos (Freidel et al. 1993:128). The central navel together with the four horizontal cardinal points forms a quincunx that is bounded by markers in the four directions at the edges of communities (Freidel et al. 1993; Vogt 1981). These boundary markers may be in the form of stelae, wooden crosses, walls, *sakbej*, or other *cenotes* or caves. Fedick and colleagues (2012) applied this concept to successfully locate such a boundary marking *cenote* at T'isil.

Similar layouts are common at Terminal and Postclassic cities like Xuenkal, whose central *cenote* and its arrogation by political elites reinforced an ideology that legitimized political and economic ties to Chichén Itzá while still maintaining a degree of autonomy. Several structures at Xuenkal are aligned to face this *cenote*, some even with *sakbej* leading toward the *cenote*, while others maintain a more typical plaza plan aligned with the cardinal directions rather than a landscape feature (Manahan et al. 2012). Clearly the association with the central *cenote* shares a similar purpose beyond the practical at both Xuenkal and Chan K'om – two sites somewhat removed in time and space. Evidence of this similarity is preserved from earlier epochs also. As early as the Preclassic and for centuries after, *sakbej* at Yaxuná made use of this cosmological geomantic site planning in politically engrained configurations and constructions (Stanton and Freidel 2005). There, the major pyramid/mountain of the Northern Acropolis towers above a collapsed cave (Stanton and Camacho 2014). The modern town of Yaxuná, situated just southwest of its ancient epicenter, is likewise centered around a *cenote*, dubbed Lol-Ha.

A *ts'ono'ot* at San Gervasio, Cozumel also drew associated architecture including a *sakbej* and adjacent temples (Patel 2005). There, the placement of a temple directly above the angled entrance to the watery cave mirrors orientations at such sites as Dos Pilas, Las Pacayas, Las Cuevas, and the Casa del Cenote at Tulum, a coastal site on the mainland not far from Cozumel. Whether associated with Ix Chel, as is likely the case at Cozumel, other deities, or simply the *cenote* portal itself, these temples clearly indicate an arrangement beyond the domestic toward these important points of connection to gods and spirits. Some sacred *cenotes* and caves can be more ominous than others and can have harmful or malevolent supernatural associations. The walls enclosing the heart of

Mayapán slightly deviate to include the ritually important *cenote* X-Coton, while excluding the *cenote* Sac Uayum, which was said to contain a child-eating flying serpent (Brown 2005:183). However, in some cases menacing forces can be mitigated through rites designed to appease or dispel foul winds or spirits (see discussion of Chan K'om below).

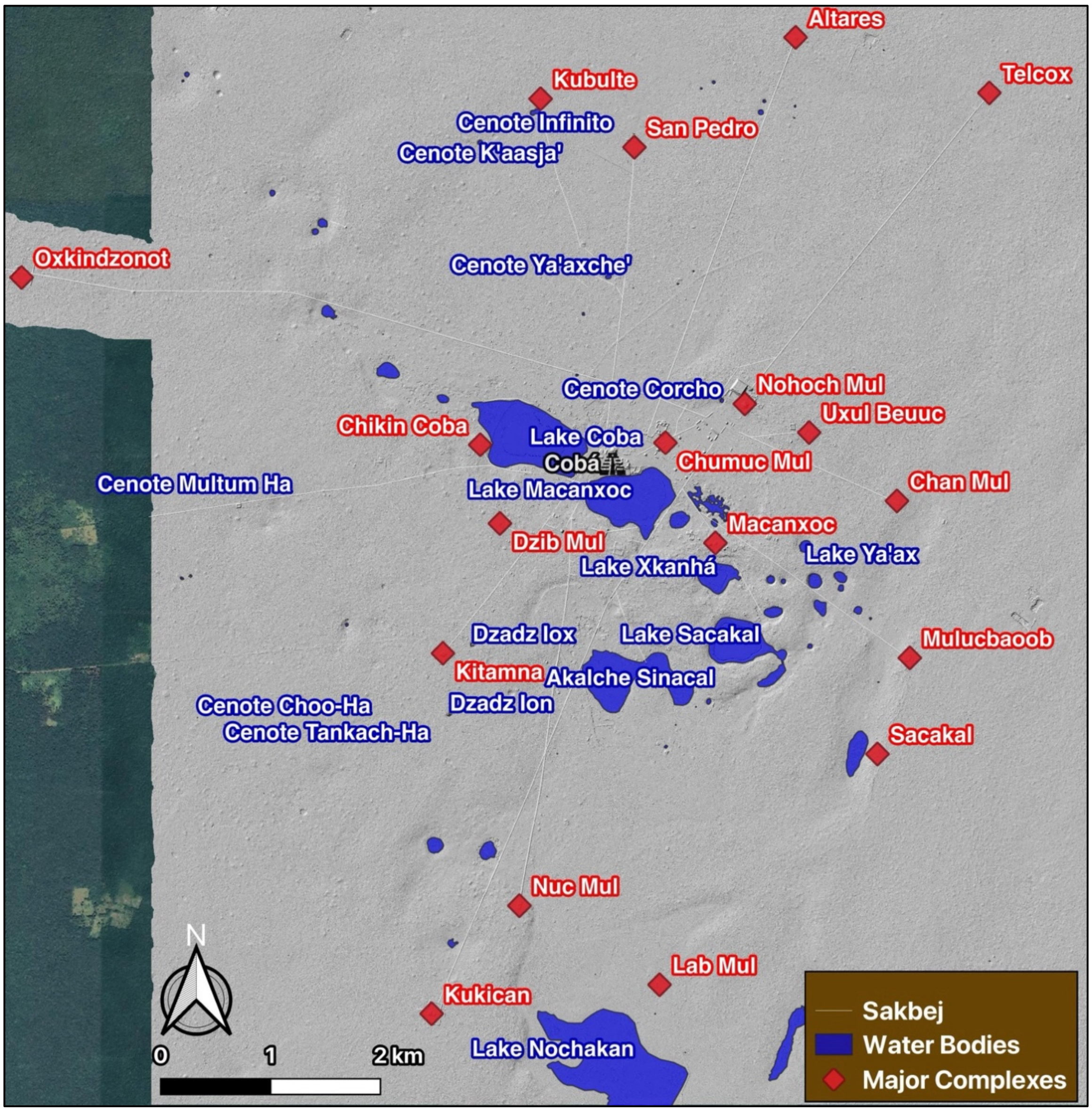

Figure 3.1 Map of major water bodies and monumental complexes at Cobá.

The centering of a city or community was not always structured around a *cenote*. At Yaxuná, early in the Middle Preclassic, the plaza of the E-Group marked the central point of the site, constructed over a small cave with ritual cache deposits including a water jar (Stanton, Dzul Góngora, et al. 2023) . In the relatively wetter Preclassic, this central pit may have filled with water, perhaps perpetually but at least through the rainy season, before it was covered. As the urban zone of Yaxuná expanded, a cross was etched into the middle of the plaza to re-center and reaffirm the spot in the memory and practice of the Preclassic Yaxuneros, (Stanton and Collins 2021), and later was shifted to a radial structure constructed in the crux of causeways keeping the quadripartite shape of the city as more monumental plazas were built (Stanton and Freidel 2005).

At Cobá, the large lakes mark the central area of the city, along with massive temple mountains like Nojoch Muul (Figure 3.1). Contemporary local legend recalls the ancient bustling market of this center through a mystical market that arises from Lake Macanxoc each New Year (Folan et al. 1983:52). In addition, the network of *sakbej* emanating from this center connects to other large structures at their termini (Stanton, Ardren, et al. 2023). Notably, most of these termini also feature a *ts'ono'ot* or other water feature(s), such as the *ts'aats'* at Kitamna (the southern Sakbej 15 terminus).

At Kukikan (the southern Sakbej 8 terminus), no such major natural water body is immediately apparent, but there are low lying circular constructions there that appear to be constructed pools or baths (Figure 3.2), in addition to Lake Nochakan (slightly larger than Lake Cobá) about 1km east of Kukikan, and other smaller water bodies north along the *sakbej*. There is also a mostly covered *ts'ono'ot* named Muul Ich approximately

2.5km south of Kukikan, along with a cave held sacred by the nearby inhabitants of the *kaajal* of San Juan de Dios.

Figure 3.2 Constructed depression filled with water at Kukikan, Cobá.

Sakbej 1 of Cobá is more of a special case. Its terminus (or origin from a flipped perspective) is the city of Yaxuná, ~100km to the west and no mere suburb or terminus group of Cobá. This great *sakbej* itself was likely a water feature, both functionally and cosmologically. The political and economic reasoning behind Sakbej 1 and its possible secondary function as a conduit for small reservoirs will be discussed in later chapters, but the symbol of the great road may also evoke the bringing of summer rains from east to west. Conceptually, roads and canals are not altogether dissimilar, and often go hand in hand and must be differentiated in schemas as on maps of the chinampas of Tenochtitlan with footprints for roads and water symbols for canals (Figure 3.3).

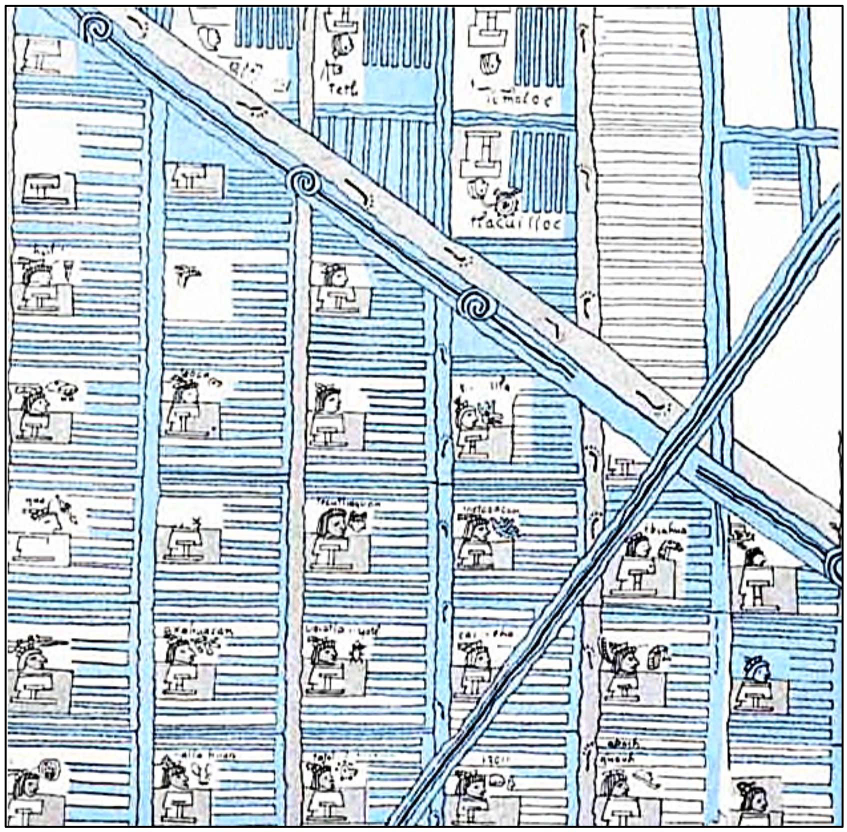

Figure 3.3 Detail of sixteenth century AD map of the chinampas of Tenochtitlan, with water swirl symbols along major canals and footprints along walkways. This map is housed in the National Museum of Anthropology in Mexico City, image after a copy printed by Michael D. Coe (1964:93).

Schaafsma and Taube (2006) discuss the ideology of rainmaking throughout Mesoamerica and beyond to the Pueblo Southwest, which shared many ideological markers. As far away as New Mexico, mountain shrines acted as sacred axis points which allowed communication with underworld spirits, and from which emanated "rain roads" (Douglass 1915). Although there are no mountains in the northern Yucatán, large pyramids served as such axis points in that region. The rain god Cháak makes a variety of appearances in the Dresden Codex, including seated in or upon canoes, *cenotes*, mountain clefts, and in some cases walking along *sakbej* (Figure 3.4).

a b c

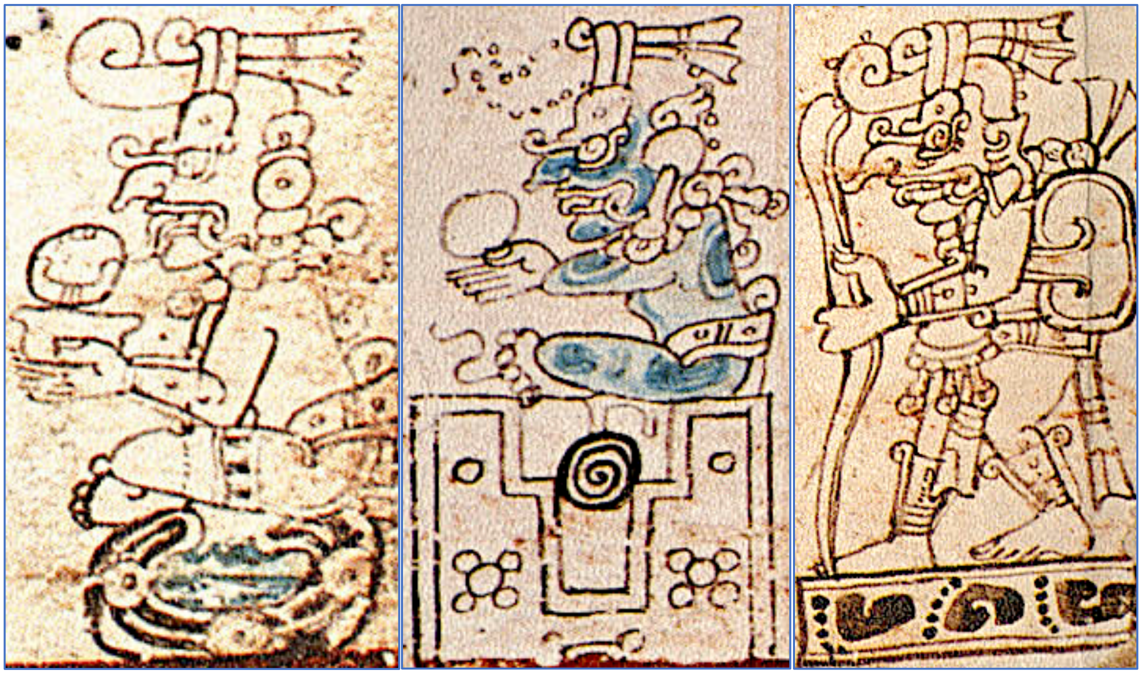

Figure 3.4 Representations of Cháak in the Dresden Codex: a) Detail of page 39c, Cháak sits above a cenote; b) Detail of page 41a, Cháak sits above a mountain cleft with a spring; c) Detail of page 65c, Cháak walks along a *sakbej*.

It is therefore conceivable that the *sakbej* emanating from Cobá represented similar "rain roads," especially Sakbej 1, all of which positioned central Cobá as the *tuuch lu'um* and conduit to the gods, including Cháak. The rounded temple Xaibe is positioned in a central location and crossroads of the major *sakbej* of Cobá and is thus a likely locale for the *tuuch lu'um*. Of note, an offering of shell pendants, plaques, and fragments was buried within Xaibe (Robles Castellanos 1990). Thus, although neither Yaxuná nor Cobá are centered around *cenotes*, their central points are nevertheless heavily associated with water, caves, and rain.

3.4 Ethnohistory and Ethnography

Despite the cosmological importance of the central *cenote*, rituals of supplication often rely on water that is *sujuy ja'* (pure/virgin/unsullied water) and collected by *aj men* (healers and ritual practitioners) in *ollas* or other special containers (Thompson 1959). For the water to retain its unsullied nature, a *cenote* must be remote enough to preclude it from common foot traffic and thus are not to be found surrounded by everyday domestic architecture, stressing the ritual significance of water sources outside of the centered spaces. In other words, there must be a spatial gulf between the *cenote* and domestic space to maintain such places as sacred (Stone 1995:17). Sacred water does not have to come from centered water sources, and in fact rarely does, as such water hubs are "polluted" by common quotidian use.

At Chan K'om, this meant water from a *cenote* several kilometers distant from the *kaajal* was needed for the rain petition ceremony known as *ch'a' cháak*, while for other rituals the water could be drawn from the central *cenote* of the village as long as it was done at dawn before it was "contaminated" for the day by the women collecting it for everyday purposes (Redfield and Villa Rojas 1934). The more distant sacred *cenote* also features a narrow-restricted access, forcing a difficult entry of which usually only the *aj men* is allowed to partake. Thus, the ideal Maya settlement, whether village or city, should contain a large *cenote* with perpetually refreshed potable water yet also be nearby enough to at least one other *cenote* or water source that can remain ritually clean and removed from domestic space. As at Mayapán, a *cenote* at Chan K'om could also be malefic, with the added temporal twist that this could be remedied with a *loj kaj* ceremony intended to remove evil winds and foul voices emerging from the *cenote* (Re Cruz 1996).

Considerations of gender pollution seem to extend to most other public sacred rituals of the Maya, although there are exceptions, both in ritual and in female age groups. Women "safely" beyond menopause could participate in ritual dance ceremonies (Clendinnen 1980). Furthermore, some rituals documented in the Colonial era were performed specially for the health and welfare of women during and surrounding childbirth (Knowlton and Yam 2019; Roys 1965). These perinatal rites involved *pib naj* (steam baths or sweat lodges), which served to purify the female body through and after childbirth, plus promote a healthy delivery. In the chants for these rituals, the water used to douse the hot rocks to produce steam is explicitly stated as *cenote* water in one line, and as hail-stone water in the next (Knowlton and Yam 2019:724). Such purification measures are intended not only for the benefit of the mother, but also the community at large through the tempering of the powerful *kinam*, an energy or force that can be transmitted, amongst other activities, through contact with pregnant women.

Some quotidian mundane domestic labor was also gendered. It was typically on women to "pursue the endless task of fetching water from the village cenote" (Clendinnen 1980:377). Importantly, this highlights the central positioning of a *cenote* as vital to the social structure of Maya society, the melding of cosmology with daily life, and how an alteration to water management strategies has the potential to change both. For example, if the village dug wells in each neighborhood (common practice in the later Colonial Period), or began pumping water into rooftop tanks for each household (common in recent decades), how might that change the relationship of the people to that *cenote*, or towards *cenotes* and caves in general for that matter? Certainly, these technological changes have had a profound impact on not only the daily life of the Maya, but also their cosmovision, and demonstrates how it is not only the Church that influences the belief systems of indigenous peoples.

In addition to settlement placing and relations of practice involving *cenotes*, the names of settlements are often the same as their primary sinkhole in the Yucatán, e.g., Kancabdzonot, Xkalakdzonot, Chendzonot, Chan Cenote, and Dzonot Aké, to name but a few. Most of these are relatively modern settlements, dubbed anew (or possibly for the first time) after the displacement and chaos of Spanish colonialism, but some associated with ruins indeed still carry their pre-Columbian names. Chichén Itzá, for example, translates as "mouth (*chi'*) of the well (*ch'e'en*) of the Itzá (Maya nation/people and patronym possibly meaning "water witches/mages," see Barrera Vásquez 1980:272)." In addition, this waterhole naming pattern phenomenon is not unique to the northern Yucatán. Lineages and kinship groups of the Zinacantan of Chiapas form "water groups," each which perform waterhole ceremonies, and are often named after these waterholes (Vogt 1976:99). We also see reflections of Classic Maya cosmology in the contemporary Zinacantan, where nearby caves and sinkholes were sacralized in addition to waterholes in the center of the villages (Vogt 1981:133), a phenomenon discussed above in the contexts of ethnohistory and settlement patterns, but equally applicable to Classic Maya inscriptions and iconography (Vogt and Stuart 2005:163).

Another thread linking the more distant past to recent history and contemporary belief structures is again found at Chan K'om (Redfield and Villa Rojas 1934), where early 20th century villagers believed that the *cháaks* (in this case multiple incarnations of

Cháak, associated with cardinal directions, colors, and various rains and weather phenomena) assembled amongst the ruins of Cobá during the dry season, and during the rainy season ushered forth westward riding horses in the sky, announced by thunder and rain clouds. "It is said that on the second of June the chaacs get their orders at Cobá, and on the third they ride forth. They issue from the chun caan [trunk of heaven] through a small round opening in the sky: the holhuntazmuyal (doorway in the clouds)" (Redfield and Villa Rojas 1934:116). Presuming this cosmovision connecting Cháak to Cobá originated much earlier, the construction of Sakbej 1 served, amongst other purposes, to reflect the rainy sky road of the *cháaks* as a terrestrial path emanating from the lake city of Cobá to better facilitate the bringing of rains to its western neighbors and, likely, subjects.

Contemporary cosmology amongst Cobañecos venerates the goddess Ix Chebel Ya'ax and connects her with the main temple of the Cobá Group known as La Iglesia in particular (Folan et al. 1983:71). Ix Chebel Ya'ax is an incarnation of (or is strongly connected with) the designation Goddess O, an aged goddess of childbirth, healing, divination, and, importantly here, storms and water, a role that strongly associates her with Cháak, perhaps even as consort in some instances (see Taube 1992:101). As a primordial goddess of creation and destruction, she often represents an overabundance of water and flooding, as scenes in the codices depict a great outpouring of water from her jar (or in the case of the Madrid codex, her breasts and loins), most famously on the last page of the Dresden codex depicting an apocalyptic deluge (Schellhas 1904:31).

Therefore, it is not likely she was prayed to or given offerings for supplicatory rains in the same manner as Cháak.

However, there were certainly many proponents of ancient interactions with watery caves that differ from contemporary practice. Classic Maya rain rituals in cities with monarchies were likely gaudier affairs, with royals and elites involved, along with musicians to supplicate the deities and spirits of rain and wind not only with physical valuable offerings but with music and fragrance (Ishihara 2008). Furthermore, ancient water rituals were not only performed in caves or at *cenote* entrances, but in public arenas where they could become public spectacles, such as the famous Maya ballcourts.

3.5 Ballcourts, Maquetas, and Cave Art

Ballcourts were ubiquitous at virtually any major site in Mesoamerica, as early as the Formative Period starting with the Olmec (Taube 2018), and as far afield as Hohokam territory (Wilcox 1991). Rubber balls preserved in the muck of spring El Manatí (along with wooden carvings, skeletal material, jade, and other offerings) indicate that the ballgame was closely associated with rain rituals and the watery underworld from its earliest conception (Ortiz and Rodríguez 1994; Taube 2018). At this spring a boulder holds a channel for directing a stream of water, or perhaps blood or other fluids, and later Maya and Mesoamerican *maquetas* possess similar such channels. Most *maquetas* are similarly carved into stone boulders, and commonly portray miniature architectural models, including temples, stairs, pools, ballcourts, and channels representing canals or aqueducts (Broda 1997; Taube 2018), which flowed with water poured over them in rituals documented in the Colonial era (Ruiz de Alarcón 1629), filling the tiny pools and ballcourts with ritual waters. Other miniature ballcourts were ceramic vessels, complete with spouts to fill and drains to empty them. Many of their life-sized counterparts, therefore, were also likely seasonally ritually flooded with water and subsequently drained, and indeed drains have been uncovered at several enclosed ballcourts in the highlands (Smith 1965).

In addition to rainwater, blood was a common theme at ballcourts, and may also have been used in *maqueta* rituals. After important ballgames, decapitation of even a small number of individuals would have coated the surface of the court with a thick layer of blood. In addition to the more typically known rubber ballgame, other ritual competitions like boxing were also prevalent in Mesoamerica (Taube 2018; Taube and Zender 2009). During bouts, boxers sporting "knuckle-dusters" (Coe 1965a) or *manoplas* (Taube and Zender 2009) would have also been easily capable of spraying ample blood from their opponents' heads (Taube 2018). Unlike the ballgame, boxing matches could conceivably be conducted whilst the court was flooded, the boxers' movements splashing in ankle-deep water as their blood sport/ritual quickly stained the whole of the watery court surface a deep red. Ballcourt markers at Tenam Rosario underlie the importance of this kind of blood sacrifice through sport by featuring squatting Tlaloc figures that "stress both militarism and renewal or rebirth" (Fox 1993:62).

The ballcourts of Cobá, Yaxuná, and numerous other sites of the flat northern Yucatán were not sunken nor enclosed within mountainside or hillside plazas like many in the highlands, but most are still found near the bases of the largest pyramids of those sites, with some ballcourts proximate to water bodies (Figure 3.5). The Great Ballcourt of

Chichén Itzá has multiple drains, and points of ingress and egress to it and other plazas and ballcourts may have been blocked during rainy seasons to deliberately flood these areas (Stanton, Taube, et al. 2023:17–18). Even if in some cases the flooding and draining of ballcourts may have been a more immediate affair, they were still connected with anthropogenic mountains in the form of built structures, and likely still connected with themes of rain, Cháak, and the watery underworld, as they are usually also positioned near *cenotes* and/or caves.

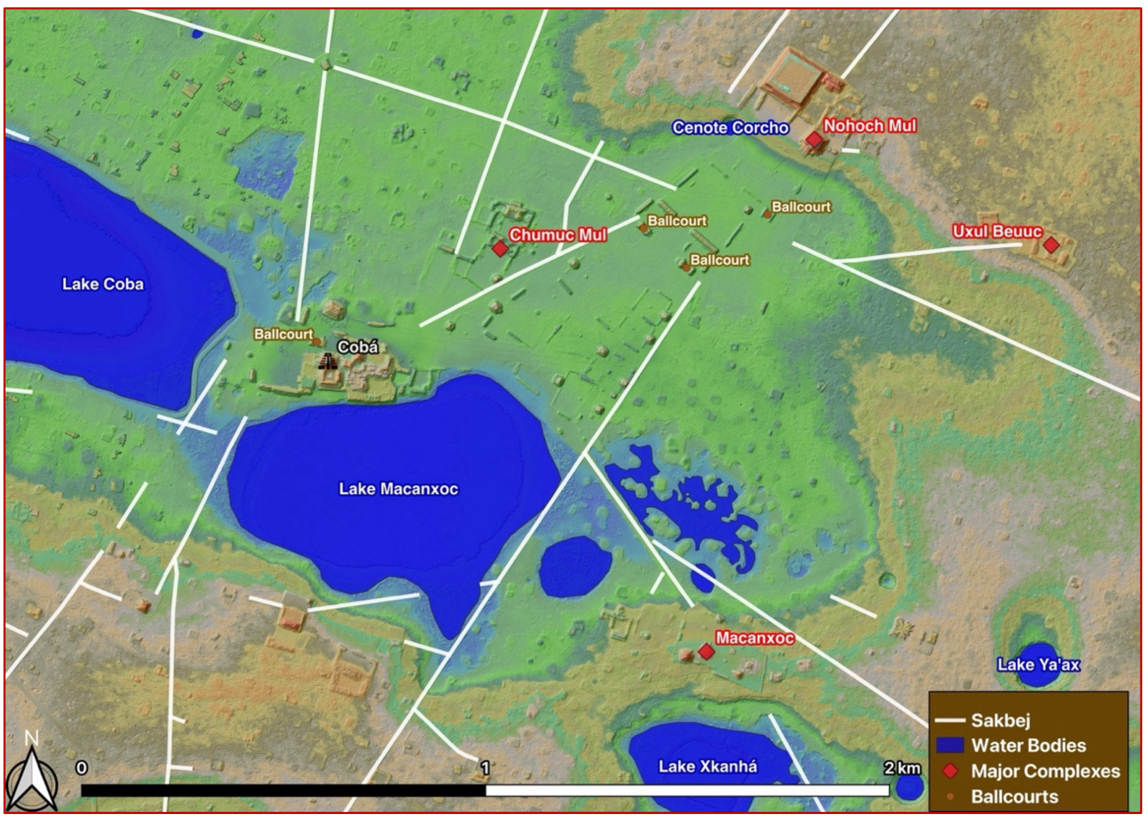

Figure 3.5 Map of central Cobá highlighting locations of ballcourts in relation to major water bodies and monumental complexes.

At Cobá there are three ballcourts in Group D southwest of the Nojoch Mul Group which continue the alignment of those massive structures toward Lake Macanxoc (Figure 3.5). The ballcourt of the Cobá Group just north of La Iglesia held a round offering container buried at center court, containing ocean artifacts such as shells, snails, and pearls imported from the coast (Benavides Castillo 1976a). Such offerings are reminiscent of those of shell and fish bones within passages of the sacred cave under the Pyramid of the Sun at Teotihuacan (Millon 1981:243), where water was drained into its passages and thus played "a major ceremonial role within the cave" (Taube 1986:54).

Some *cenotes* and caves of the northern Yucatán themselves house *maquetas* and depictions of Cháak, along with *ollas* and *jaltun* collecting the slow drip of cold cave water from speleothems. Loltun Cave, for example, is home to several *maquetas* with small carved grooves for flowing water down or along their miniature stairways (Thompson 1897). The dark of Loltun also covers reliefs with glyphs and a personage dubbed El Guerrero (Andrews 1981) carved during the Late Formative with iconographic features connecting some of the elements and regalia of the figure to Cháak (Grube and Schele 1996), perhaps a ruler or priest impersonating or evoking the rain deity.

Boxers, Cháak, and cave iconography also sometimes share a common thread of male virility and fertility, with depictions of Cháak as boxer with enlarged phalli on ceramic vessels (Taube and Zender 2009:187), and explicitly sexual mud sculptures connected to the Zapotec version of the rain god, Cocijo, found within Cueva del Rey Kong-Oy (Winter et al. 2015; Winter 2020). These depictions likely evoke not only human (and animal) fertility, but also agricultural fertility secured by the rains, the lifeblood of agricultural communities. For similar reasons did Maya lords bloodlet through penis perforation (Stuart 1984; Thompson 1938, 1961).

Placement within a cave is important to the context of cave art and carvings. Even very simply rendered faces can be confidently associated with water ritual, as they appear at entrances and pathways toward water within caves (Rissolo 2003, 2020).

3.6 Epigraphy and Iconography

As previously discussed, the transition of water management strategies from the Preclassic to Classic periods in the Southern Highlands, Petén, and elsewhere were partially due to a general drying and also in part to demographic shifts. It should be stressed that this transition of water management strategies was not a defining characteristic of all major Maya cities and polities, nor undertaken in the same ways universally, chiefly because many such centers sit outside of the Petén or other swampy regions. Water management over time is not thoroughly understood throughout all of the Maya region, and some cities and other settlements may not have experienced nor needed such a shift in water management strategies during such transitions.

Palenque, for example, was built around and between rushing rivers, waterfalls, and springs in an area that receives considerable quantities of rainfall, even during the "dry season." Rather than a strong need to conserve water in reservoirs or *chultun*, the architects of Palenque devised methods to channel and manage water, including aqueducts, bridges, dams, drains, walled channels, pools, and even utilized water pressure systems (French and Duffy 2010). Many of these features are found elsewhere but were particularly well-engineered at Palenque. Underground aqueducts surged beneath plazas and structures that abounded with watery iconography, such as water band motifs. Rivers and streams were thought to be related to water serpents known as *witz'* (not to be confused with *wiits*/*witz*, mountain) in Classic Maya hieroglyphs (Stuart 2007), and later as Ch'ijchan to the Ch'orti' (Wisdom 1950). Water serpents were associated with movement and power, bringing hurricanes (Houston 2006; Wisdom 1950:394) and controlling the movement of water. Thus, Maya kings aligned themselves with these mythical creatures as intercessor, impersonator, and/or personification of water serpents (Schele and Miller 1986:46) and other deities and supernatural beings in their role as water provider in order to assure crop productivity and fertility (Brady and Ashmore 1999:129–130).

The glyphic inscriptions at Palenque are also telling, which serve to showcase its water abundance. Lakamha' was the Classic Maya place name for Palenque itself, as deciphered from its toponymic glyph, which translates to "large waters" (Stuart 2005:90), a fitting name for a city with a river running through it and surrounded by streams, waterfalls, and springs. Toponym glyphs were often used by the Maya to denote a ritual act by a ruler at a certain place, usually sacred caves and springs associated with the site. For example, Temple XIX at Palenque contains carved panels, the south of which ends with the expression "*ut-iiy tahn ch'e'en Lakamha'*, 'it happened before the spring of Lakamha'" (Stuart 2005:90). Temple XIX is situated directly in front of the foremost spring and font of this river, and the name of the site itself is tied to this spot and sacred place in the landscape, along with the entirety of the issuing river.

Thus, we can determine a site plan based on building structures oriented to such sacred spots not only from spatial data but confirmed and explained by epigraphic and linguistic data. In addition to Temple XIX, the three structures which make up the Cross

Group at Palenque were also built in orientation toward this spring, vying for similar ritual sacred significance in such prime real estate. The phrase *ut-iiy tahn ch'e'en* is also found in front of other toponym glyphs of other sites and serves a similar purpose of placing the site in the context of a sacred ritual place and tying the ruling elite to the same as the owners and caretakers of the site, after a fashion. As at Palenque/Lakamha', the "it" that happened may have been a calendrical ritual or other ritual ceremony overseen by the lord and taking place at the spring, cave, or associated structure.

The example of Palenque serves to demonstrate how water symbolism and iconography is not merely ritualistic or cosmological, but also ideological and political. These rituals and symbols served to ingrain the leaders into their positions of power, through "an association with the political economy and how access to and distribution of water, land, and food separates society and leads to methods of sociopolitical control" (Scarborough 2006:230). Water bodies were also vital for economic features like marketplaces, which needed nearby water sources to facilitate their smooth function, so elite control of water would have not only controlled the economy through production but also through distribution. These elite rulers or *ajaw* (lord/king) also became priests and/or divine kings responsible for maintaining the elements and sustaining the rains and an ample supply of potable water. Thus, the *ajaw* became directly responsible for agricultural productivity and sought to control actual water bodies while classifying their palaces and temples as cosmological caves and water sources both through iconographic/glyphic portrayal and through ritual affirmations and calendar ceremonies.

“The landscape itself thus loudly proclaimed the king’s control over water, and presumably over rainmaking and fertility” (Brady and Ashmore 1999:130).

Some cities and their rulers were associated with particular patron deities. According to the Chilam Balam de Tizimín (Edmonson 1982), for Cobá this was Múuts'en Kaab, god of bees and honey, and perhaps associated with the descending figure portrayed at the summit of Ixmoja (Nojoch Muul) and elsewhere (see Tozzer 1941:144), although in most cases this figure represented a variation of the Maize God. As another place of great waters, Cobá was and still is a paramount locale for honey production, as the *ko'olel kaab* or *melipona* (an autochthonous stingless bee renowned for its medicinal honey) requires plentiful water and floral vegetation. To demonstrate this blending of god/priest/lord, later in the same version of the Chilam Balam (Edmonson 1982:40), Múuts'en Kaab is a lord who travels underground with the nameless 13 gods in order to claim lordship of *katun* 11 Ajaw.

Another significant god at Cobá is Ek' Chuaj, a merchant god heavily concomitant with cacao (Taube 1992:88). Cacao iconography was also often associated with the Maize God (including its descending form), and at times with K'awiil (Figure 3.6, see also Martin 2006), a god of lightning and fertility associated with agriculture and water bodies (akin to Cháak in many ways). Diego de Landa reported (Tozzer 1941:164) that during the month of Muan, cacao farmers would sacrifice chocolate-spotted dogs as part of a festival in honor of Ek' Chuaj, Cháak, and Hobnil.

Figure 3.6 K'awiil emerging from a cenote with cacao pods growing from its edges and above. Reconstruction of a painted capstone from the Temple of the Owls, Chichén Itzá. Colorized interpretation by Patrick Rohrer after a photograph by Alfred M. Tozzer (1957: Figure 5).

Hobnil was a term for the hollowed-out tree trunks used to house *melipona* hives; the eponymous god appears as a *bakab* in other rites (Tozzer 1941:157), and is also strongly associated with Múuts'en Kaab, as either or both may be invoked for *u hanli kaab* rites, aimed toward beekeeping. Maya lords often personified a specific *bakab* during such rites. These directional *bakab* (or Pauahtun) could also be directional Cháak, and it is telling that Cháak is correlated with these major deities of Cobá, as the waters of Cháak were vital both for beekeeping and cacao growing. In fact, a passage from the Chilam Balam of Chumayel appears to parrot the ritual language from several pages of the Dresden Codex (Bolles and Bolles 2021:164), but replaces the directional Cháak with directional Múuts'en Kaab.

Another way to claim sacredness, primacy, and cosmological supremacy was through glyphic representations of the name of the site itself, along with the dynasty in control. Both of these attributes are to be found in Emblem Glyphs (Berlin 1958), a formulaic glyphic set associated with Classic Maya cities that usually titles a ruler – often as a *k'ujul ajaw*, or "divine lord" – and sometimes identifies the polity, city, or area over which they rule. The typical *k'ujul ajaw* formula contains a beaded "water-group" element (Thompson 1950) in the opening of these compound glyphs that has been interpreted as a metaphor for royal blood (Stuart 1984). I propose that it is just as likely that these divine/royal water droplet glyphs are related to the idea of *sujuy ja'*, which would stress the responsibilities and privileges of the ruling elite to properly manage and control such unsullied water as clean potable water sources for everyday use, the success of which allowed them further pretext to connect themselves with the divine. However, the typical formula has many deviations or is omitted entirely from sequences that almost certainly have an Emblem Glyph. Perhaps the water group is used for discussing the ritual duties of the leader. Indeed, it seems that many Emblem Glyphs throughout the Classic Period have a water aspect beyond the typical water group formula, whether it is in the form of a *ja'*, *ba'*, or *nab* glyph, or other watery reference.

The glyphic and artistic representations of water features, caves, and ideas associated with them present overlaps and conflations in design. Openings of caves (wet or "dry") are often represented by the maw of a great Earth Monster, sometimes also known as the Kawak/Cauac Monster or Witz Monster (Stuart 1987). Large stucco Witz masks adorn the bases of monumental architecture at several sites, including Caracol and

Uaxactun (Valdés 1987), often with water scrolls, fish, and other watery imagery that again reference the plazas before them as watery places, and perhaps positioning the built temple mountain/cave *áaktun* as producer of clouds and rain. In some cases, the maw surrounds the doorway of a structure (Figure 3.7), making this connection even more explicit.

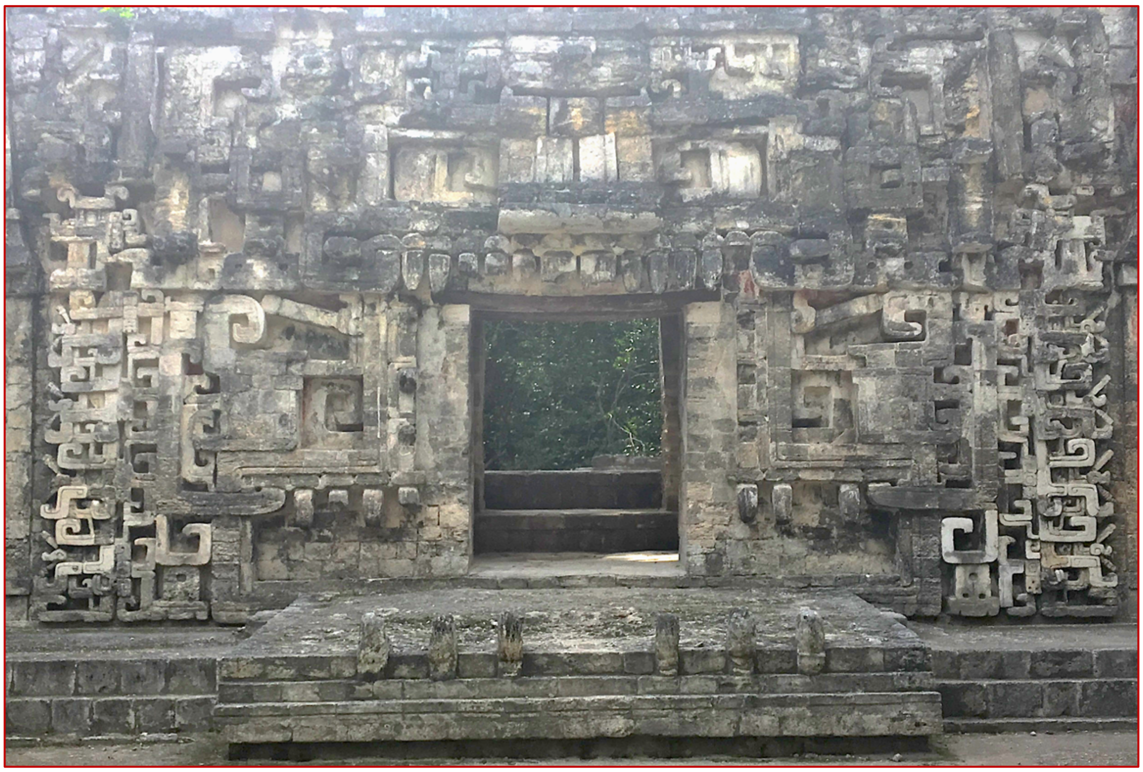

Figure 3.7 Witz Earth Monster surrounding the doorway of Structure II at Chicanná, Campeche.

The form of the Witz "monster" varies regionally and temporally (see Taube 2004), but is usually zoomorphic and reptilian, its curled animal snout sometimes leading to confusion with Cháak or other deities (Taube 2004:85), and its mouth often depicted with large fangs and/or a skeletal mandible. Often, this jaw appears as the curved poisonous claws of a centipede, which are technically not actually jaws but a pair of the centipedes many legs which are modified forms called maxillipeds that contain poison glands and are tipped by tarsungulum (Taube 2003b:415).

a b

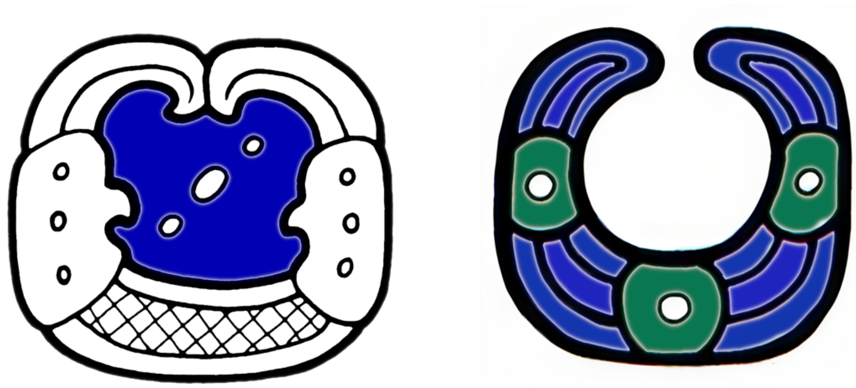

Figure 3.8 Maya hieroglyphs of watery caves or *cenotes* (though possibly reading WAAY). a) This glyph depicts a skeletal centipede maw and more common in the Classic Period Southern Lowlands. b) This later version more common in the Postclassic (as in the codices) and in the Northern Lowlands features jeweled disks and is perhaps more reminiscent of the water serpent. Colorized interpretations by Patrick Rohrer after drawings by Marc Zender (Stone and Zender 2011:135).

The centipede maw is also depicted in hieroglyphic representations of *cenotes* (Figure 3.8). This alludes to the dangerous, poisonous, skeletal underworld, and reminds us (as it did the Classic Maya) that although many *cenotes* contain fresh cool life-renewing waters, other *cenotes* and caves may produce diseased waters if they are too stagnant and polluted, too high in certain mineral content, or home to an abundance of bats and their guano, or other species that may envenomate more directly like snakes or centipedes. In fact, a species dubbed *Xibalbanus tulumensis* (Hessler and Yager 1998; Yager 1981) was the first recorded venomous crustacean, which greatly resembles an underwater centipede, despite being quite removed evolutionarily speaking. This and related species only occur in anchialine cave systems where there is mixture of saltwater and freshwater underground.

Sometimes the line between mythology and reality, and between gods and rulers, becomes as blurred as a halocline. The primordial dark watery mythical *cenote* as a birthplace for the sun or sun god is exemplified in glyphic text on Zacpeten Altar 1 (Stuart 2009). The centipede maw appears directly after the upturned frog glyph for birth. The Zacpeten Altar links this mythological birth or rebirth event with a particular ruler and historical event. The scene in Uxmal Stela 14 shows Cháak standing above a *cenote* which contains two sacrificed captives. Kowalski (1985), however, identifies the personage of Cháak as a ruler of Uxmal who here impersonates the rain deity. Deity impersonation is not uncommon amongst Maya lords and rulers (see Taube 1992), as mentioned earlier in the discussion of the water serpent.

One of the major ties between water imagery and leadership in Maya iconography is the portrayal of the water lily. Flowers in general are connected to caves and portals, as they both are represented by quatrefoil designs, and flowers themselves are portals for supernatural forces in Mesoamerican thought (Taube 2010). The enigmatic water lily appears in Mesoamerican art in an even greater variety than the many species, colors, and sizes of the plant itself. Willey (1980:262) emphasized the importance of the water lily in relation to water management subsistence, noting its depiction amongst other creatures and plants are "especially at home in sluggish riverine, pond, or swampland (*bajos*) settings." Water lilies tend to bloom at the start of and throughout the rainy season, connecting them to those replenishing rains vital to agriculture. Their ubiquitous appearance in the *cenotes* and other pools and wetlands of Mesoamerica appears to ascribe them a sacred status, which is reflected (sometimes literally, with mirror glyphs/representations) in their artistic stylings. The *witz'* water serpent (discussed above) is commonly portrayed with water lilies, and indeed has been dubbed Waterlily Serpent (Taube 1992:59) and Waterlily Monster (Schele and Miller 1986:46).

a b c

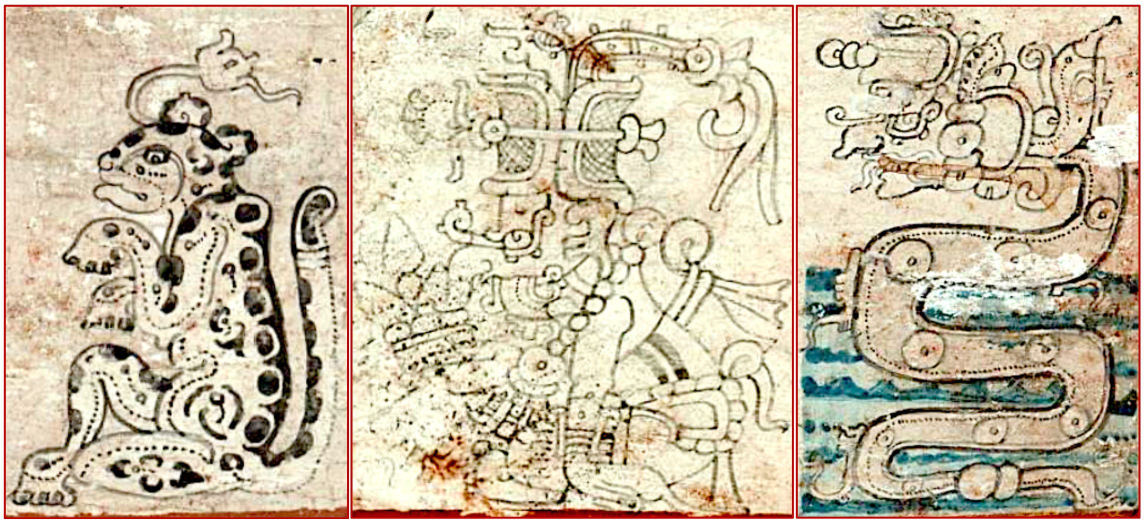

Figure 3.9 Figures with water lily headdresses in the Dresden Codex. a) Detail of page 8a, Water Lily Jaguar; b) Detail of page 13a, Cháak with water lily headdress; c) Detail of page 35b, Water Serpent with rhizomes and other water lily elements surrounding head.

Of the four codices which escaped the fires of Fray Diego de Landa, the Dresden appears to be the sole clear bearer of water lily iconography, although this may be in part due to its status as arguably (contending with the Madrid) the finest and most "complete" or intact extant codex. Pinpointing the exact origin locale of the Dresden codex is problematic due to the wide area of similar iconography at the time. Thompson (1959) divided the work into fourteen separate chapters that reveal a great deal about how the Maya may have consulted these sources of knowledge. The water lily appears (at least) thrice in the Dresden Codex as a headdress motif, but each time adorning a distinct – yet related – creature or character: The Water Lily Jaguar, the Water Serpent, and a version of Cháak each grace the pages of the Dresden bearing water lilies (Figure 3.9), exemplifying a strong continuation of core elements of Classic Maya cosmology and mythology into the Postclassic, and their connection with rulership. For example, a jade figurine of the Water Lily Jaguar was found in a burial of a ruler in Tikal (Scherer 2015) who reigned during the Classic Period.

Lol ja' and *nikte' ja'* are the primary terms for water lily in Yukatek Maya today, but a less common expression is *xikin cháak* (Cháak's ears), and many Classic Maya iconographic expressions of Cháak include water lily ears (McDonald and Stross 2012). *Nab* is an older Yukatek and Itza' word for water lily and its glyphic representation (Figure 3.10c). Many scholars (e.g., McDonald and Stross 2012; Willey 1980) have conflagrated the glyph denoting *ja'*, meaning "water" (Figure 3.10b), with the glyph for *naab*, meaning "pool" (bounded water, *cenote*, or ocean), "water lily," or, significantly, "plaza," (Freidel et al. 1993:139) as, like ballcourts, plazas could represent the watery underworld, could be flooded, and some held cisterns in their centers or reservoirs at a corner or side into which the plaster plaza would have directed water.

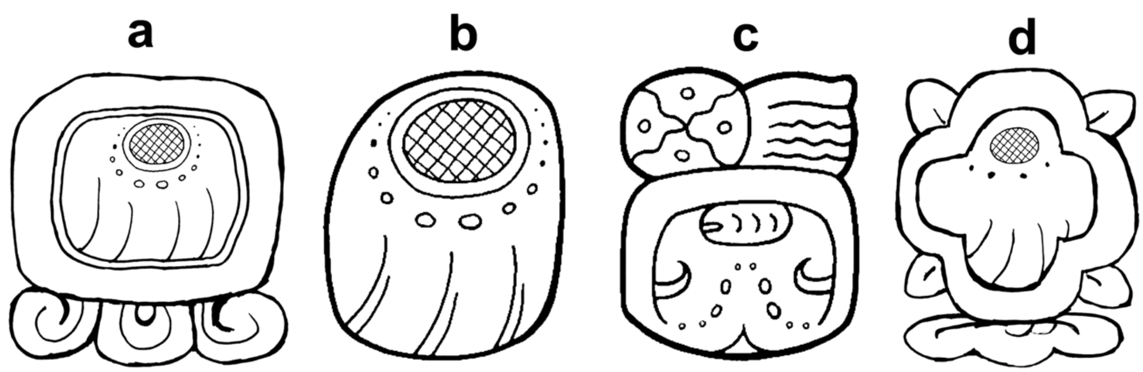

Figure 3.10 Maya hieroglyphs relating to water lilies. a) Imix, first day sign of the *tzolk'in* calendar; b) *ja'*, water; c) *naab*, water lily; d) Machaquila emblem glyph.

This common conflagration of *ja'* and *nab* is understandable, as the *ja'* glyph is certainly derived from water lily iconography, and their syllabograms are even combined at times, as in the full name of the famous K'inich Janaab Pakal of Palenque. In line with much of Maya vocabulary that makes it difficult to immediately pin down a singular notion, both morpheme and hieroglyph have a number of other possible meanings, mostly water related (see above). The place name, or emblem glyph of the site of Machaquila in Guatemala is a quatrefoil version of the *ja'* glyph (Figure 3.10d) with leaves or flower buds reminiscent of both the Dresden Codex and Cancuen Panel 3. This is accentuated by water lily headdresses worn by Machaquila lords standing over a similar design on stelae and a built quatrefoil within the main plaza at the site (Stuart and Houston 1994).

Although there are several dozen species of water lilies in the Nymphaea genus alone, the two main varieties predominant in Mesoamerican territory are *Nymphaea ampla* (American white waterlily) and *Nymphaea odorata* (fragrant waterlily), with the former being the most common in the Yucatán. They grow in abundance in still or slow-moving water and add attractive blossoms to the setting, but more importantly play a role in fertilizing soil and feeding fish. These two attributes would have made waterlilies very practical to the fishing and agriculture of the early Maya and an indicator of a healthy and prosperous area. Water lilies also recycle waste, a monumentally important attribute in densely populated areas where they can help prevent eutrophication in lakes and *aguadas*. They reduce evaporation, saving more water for consumption and irrigation through the dry season, and perhaps even staving off the kinds of droughts that come more from intense heat and evaporation than from mere lack of rains.

Therefore, the water lily may have been used as an elite headdress to denote the ability of the elite to maintain full thriving pools of water. “The term *Ah Nab,* or

‘Waterlily People,’ with which Maya nobles referred to themselves, underscores this connection” (Davis-Salazar 2003:278). Carvings at Pomoná portray *sajal* (subordinate lords) with waterlily headdresses (Stuart 2004), perhaps a demonstration of the ability of the *ajaw* to control and maintain these important plants, both cosmologically and materially. At the celebrated site of Copán, Davis-Salazar (2003) makes a strong case for this relationship between water management and the icon of the water lily; the underlying idea: he who controls the water controls the people. In addition, leaders needed to establish a link between themselves and the ancestor-inhabited landscape (especially bodies of water) to legitimize their position. Like Palenque, there was an abundance of water at Copan, built around its eponymous river. However, it is possible that during the rainy season the rushing river could lead to a turbidity that would render the water non-potable. If so, the river would still be usable for agricultural and other purposes, while reservoirs and wells provided potable water for domestic and other uses, as at nearby Quirigua (Ashmore 1984).

Such a scenario is also probable for the lakes, *cenotes*, and other water bodies of Cobá. In fact, the etymology of Cobá may be *kob ja'*, or turbid waters (Thompson et al. 1932). Although not rushing rivers, heavy rains can still bring high levels of turbidity and pollution to lakes and even *cenotes* (discussed further in Chapter 4). In 2018, an abundant rainy season closed access to the few *cenotes* normally open to the public at Cobá, for that very reason. To mitigate such issues, it is probable that ancient Cobanecos looked to water lilies to aid in the purification of water sources. While the rulers of Cobá are depicted in stelae primarily with K'awiil headdresses and other iconography emphasizing their role as supreme warrior and ruler, it is worth bearing in mind that a glyph variant for their high title of *kaloomte'* depicts Cháak, axe in hand to bring lightning and storms. While this may be metaphorical and still more focused on the military attributes of Cháak, it also references the "violent storms that are part of the tropical environment ... storms that destroyed but also gave life by breaking through the dry, parched surface of the earth to bring life to the maize seeds/human buried inside" (Guenter 2014:414).

Water lily headdresses may have not been exclusive to the elite, however. At a *ch'a' cháak* ritual in Yaxuná, the primary assistant (conceivably a smaller scale *sajal*) of Don Pablo (the local *aj men*) would tie a headband with a bound small leafy twig dangling outward (Freidel et al. 1993:423). While not necessarily a water lily, this appears very reminiscent of the dainty headdress adornment of a single water lily flower or bulb depicted in the Dresden codex and on Classic Maya ceramics, stelae, and murals. The association with a rain ritual underscores this connection.

3.7 Temporal Cosmology

In addition to sacred landscape features, there are also particular times that the Maya venerate. In fact, the process of centering a community around a *cenote* or other *tuch lu'um* - or centering a *kool* (*milpa*) before planting or a *naj* (house) upon building - was not only an emplacement within cosmological space but also of cosmic time, harkening back to the creation itself, the raising of the sky, and the life and land conjured out of the Primordial Sea (Freidel et al. 1993). The quadripartite world this created also is inherently bound with time as it charts the arrangement and movement of the sun from *lak'in* (east) to *chik'iin* (west) and was/is re-established annually (Coe 1965b; Tozzer

1941:135–150). Many ancient sites exhibit architectural alignments toward the equinoxes and/or solstices, perhaps most famously at El Castillo of Chichén Itzá, which forms undulating shadows along the northwest balustrade, evoking a diamondback pattern of the descending *ts'áab kaan* (rattlesnake) body of K'uk'ulkan, whose sculpted head resides at the base.

The illustrious Maya calendar is also testament to the veneration of certain times that often evoke anniversary dates of creation and other important events, and Classic Maya stelae often mark the celebrations of period endings/beginnings or other calendrical milestones. The calendar itself is directional, as the four "year bearer" new year dates have cardinal direction associations (Stuart 2004). The Chilam Balam and the codices map the stars and relate astronomical and calendrical changes to prophetic cycles of warfare, famine, pestilence, and climactic calamity. On a more mundane day-to-day or seasonal level, calendrics and day keeping serve as a kind of meteorology or Farmers' Almanac.

For early 20th century Mopan-speaking Maya of San Antonio Corozal, Belize, the agricultural year began on February 8, celebrated in part by burning copal and drinking rum, while the Lacandones celebrated the same by renewing incense vessels in mid-February, both of which Thompson (1930:41–42) connects back to the renovation of Cháak witnessed by Landa during the time of Spanish conquest, and much earlier to agricultural new year celebrations of the Classic Maya. Building from the work of Girard (1949, 1966) with the Ch'orti', who also celebrate the initiation of the agricultural year on February 8, Freidel, Schele, and Parker (1993:114–116) also find many parallels with the Classic Maya calendrical and astronomical observances, such as Wakaj-Chan, when the Milky Way and the ecliptic form a cross during the start of the *canícula*, a short hot dry period within the rainy season.

Today in some Maya communities of the Yucatán there are those who practice a type of rain and weather divination known as Xok K'iin or Cabañuelas. For, as they say in Yukatek Maya, "*wa mina'an cháake', mina'an ba'al jaantbil*," that is, "if there is no rain, there is nothing to eat." In January, villagers will observe a variety of things about the weather, the behavior of animals, and often will leave out small bits of salt in rows to judge humidity. Doing so, they draw inferences from each day which corresponds to certain aspects of months for the rest of the year, and this aids them to predict whether the year will be heavy with rain or light, if the rainy season will begin early or late, and so forth. The *milpa* or *kool* is important not only for the crops themselves but also for hunting. Another expression, "*yaan bak' ich kool*," or "there is meat in the *milpa*," refers to the growing of extra crops for deer and other game that will be drawn to the milpa and thus easy and convenient to hunt. All of this depends on the timing of the rains, to know when to burn the *k'áax* (forest/wilds) to make a *milpa* plot (too early and the ash blows away before it can add to the soil, too late and it won't burn), when to plant seeds, and the Xok K'iin has regained some popularity to guide *milperos* in timing those tasks.

3.8 Conclusion

Earlier, I contemplated the influence of changing water management technologies on Maya cosmology and ideology. More to the point of the current research, how might a severe climate change like a drought alter their perceptions of and interactions with *cenotes* and the watery underworld? Lucero and colleagues (2011) observe sharp increases in monumental constructions and ritual activity during the Terminal Classic droughts, ostensibly to placate Cháak and bring back the rains and an environmental balance conducive to their agricultural pursuits. Although they concede that this time period was tough on all inhabitants of the region, clearly the large-scale abandonment and the cessation of dynastic rulership of so many major cities at this time clearly indicates that "farmers adapted, kings did not" (Lucero et al. 2011:486). The departure of royal courtly life was clearly not the demise of the Maya cosmovision with its strong relationship to the waterscape and to rain, weather, and climate. This research, therefore, contemplates the cosmology and ideology surrounding *cenotes*, caves, and water for the Maya, both the fundamental perspectives that have continued to the present day and the societal shifts in the face of climate change, political upheaval, and other forces.

Chapter 4 Geology, Pedology, & Hydrology of The Northern Yucatán Peninsula

4.1 Introduction

The northern Yucatán peninsula (Figure II.II) has some environmental and geographic peculiarities that are very important to aspects of this research. Its karstic soil, flat platform, climatic gradient, and particular hydrology lacking surface rivers (yet comprising the largest known subterranean river, Sistema Sac Actun) all result in an environmentally entirely dissimilar area from the rest of the greater Maya cultural region. Eric Wolf (1959:13) went so far as to say of the jungles to the south that "so dense and impassable does it become that, as far as communication is concerned, the peninsula is almost an island." Even within the northern Yucatán, certain regions and microenvironments produce distinct landscapes, to be discussed in this chapter. These particularities and differences set the stage for equally particular water management strategies and levels of resilience to climate changes. Appositely, the Yaxuná-Cobá corridor is an inland hydrologic and geologic area well-positioned between and surrounded by others with varying characteristics.

4.2 Formation of the Landscape and Waterscape

The geography, geology, climate, and hydrology of the Yucatán peninsula is, in many respects, similar to the Florida peninsula that constricts the opposite end of the mouth of the Gulf of Mexico. Both are generally flat and near sea level, are primarily composed of limestone, are inundated with seasonal thunderstorms and hurricanes, and are home to many sinkholes that expose the freshwater aquifer lens beneath the surface terrain. However, there are a number of aspects that differentiate the Yucatán Platform from Florida and indeed from most other karstic landforms, rendering it quite unique. Foremost among these is the Chicxulub Crater, an impact structure approximately 180 km in diameter (Kring et al. 2004), spanning much of the northwestern portion of the Yucatán and a large chunk beyond into the Gulf of Mexico. The massive superbolide that caused this formation was over 10 km in diameter (Hildebrand et al. 1995:415). This asteroid (or other large object) crashed into Earth at the end of the Cretaceous Period (and thus Mesozoic Era), roughly 65 mya, and annihilated many species of dinosaurs and other creatures, leaving behind a geologic layer with high levels of iridium found worldwide known as the K-T boundary (Hildebrand et al. 1991:898).

The legacy of this event is especially important to the geology and geography of the Yucatán Platform in regard to archaeological endeavors, as the distribution of raw materials like quartz and chert are heavily influenced by that enormous impact, as are variations of limestone appropriate for either stone building materials or lime plaster manufacture. Tektites (glass rocks formed as molten ejecta during large impacts) could be mistaken for speleothems or even obsidian, if worked. Though rare in Mesoamerican archaeological contexts, tektites have been discovered at Maya sites like Tikal (Hildebrand 1994), and in and around the San Ignacio area of Belize (Cornec et al. 2013).

The landscape and waterscape of the peninsula is also shaped by the Chicxulub event, which is what makes understanding it so crucial to this research. The relic form of the Chicxulub crater rim is difficult to discern at first glance through typical aerial or satellite imagery due to millennia of geologic processes, a relatively flat profile, and jungle cover of the region today. Nevertheless, one of the defining characteristics of this

5km thick crater lip is its extraordinarily dense concentration of *cenotes* - even relative to that of the already prolific rest of the northern peninsula - earning it nicknames like "Cenote Zone" and "Anillo de Cenotes", suggesting an elongated cryptorheic water basin or naturally formed moat existed in this area through the Tertiary period, after impact (Pope et al. 1996). Such a basin would dissolve the limestone with groundwater, creating ring faults and laying the literal groundwork, sedimentation, and water flows resulting in the density of *cenotes* and caves so prevalent in the area today.

Both the Chicxulub impact and moreover the nature of its karst landscape leave the northern Yucatán especially lacking large truly endorheic basins, or closed lakes. Most water bodies connect to the aquifer, or their water percolates through the limestone below and evaporates, leaving few large permanent water bodies above the water table. This contrasts with other areas of the Mundo Maya, such as Lake Atitlán, a large endorheic lake whose water level rises quickly, which presents problems for communities along its bank today. Ancient peoples faced the same problems, as attested by the site of Samabaj, built around 300AD on an island on the south end of the lake that is now roughly 30m underwater (Medrano 2015).

Despite the importance of the Chicxulub event, the geologic history of the Yucatán begins much earlier than that episode, and extends afterward another 65 million years until today, of course. There has been much study of the geology and hydrology of the peninsula (e.g., Beddows et al. 2007; Collins et al. 2015; Jaijel et al. 2018), but most of these deal with relatively recent history in terms of geological epochs. On the surface, a full and complete geological history of the Yucatán Shelf is difficult to determine due to a lack of many exposed diagnostic layers, the difficulties of exploration in the jungle-covered interior and mangrove-covered coasts, and a dearth of data from deep wells. However, almost half a century ago PEMEX (Petróleos Mexicanos) drilled 10 exploration wells in the region, mostly in the state of Yucatán, in search of possible oil reserves. Several of these wells were over 2,000 m deep, and thus a great boon to a deeper understanding of the Yucatán's geologic past. The data extracted from the test drilling indicate extant metamorphic layers dating as early as the Paleozoic (Ward et al. 1995). The impact region is some 500 m of breccia and andesite glass, while in some regions up to 1,000 m of limestone and marl sits atop that (Hildebrand et al. 1995:415), reaching up to the modern surface bedrock.

The hydrology of the Yucatán follows a similar pattern through these epochs. Due to its shallow shelf which continues into the sea, the shoreline of the Yucatán Peninsula has fluctuated drastically over the eons, another history it shares with Florida. Throughout most of the Cretaceous Period, much of the Yucatán was a shallow seabed, during which time thick layers of limestone and other sedimentary layers typical of karst formations (such as dolomite) were deposited. Combined with a gentle slow uplift in the isthmus of Tehuantepec and beyond, its altitude slowly but steadily increased, even as most of the peninsula remained submerged. This process continued well into the Cenozoic period, and in many respects still continues today, but the dawning of the Pleistocene and its cycles of glaciations saw a dramatic shift in the landscape and waterscape of the Yucatán. The sea levels dropped, and the Yucatán Platform was exposed to such a degree that it was almost twice its current surface area in terms of exposed land above sea level, mostly toward the north and west into what is now a shallow region of the Gulf of Mexico. This landscape again fluctuated between glaciations, as more calcium and limestone layers were deposited, and continues to slowly change as land and sea resume the dance through our current Holocene (aka Anthropocene, and/or in this case Mayacene, in part). Indeed, even some Classic Maya coastal sites are now underwater, such as Ek Way Nal, Belize (McKillop et al. 2019).

In terms of sea level change, however, the contemporary story is one of relative stability when compared to the abrupt climate change of the Younger Dryas, though karst and cave formation processes march forward. The acidity of the rainfall combined with tannic acids in surface groundwater and porous limestone lead to heavy percolation of precipitation and most groundwater into the underground aquifer and cave systems (Gaona-Vizcayno et al. 1980). Due to past fluctuations of water levels, many collapsed dolines or sinkholes created karst windows to this subterranean water lens, primarily known as *cenotes*. These windows not only allow access to fresh water by surface dwellers, but they also enrich underwater environments with organic and biochemical nutrients that wash into them. Unfortunately, this also literally opens up these systems to the possibility of heavy pollution from pesticides, herbicides, fungicides, other industrial waste, and local general trash finding their way down as well. Through currents, tides, heavy rainfall, and/or flooding, this can have far-reaching effects beyond the location of entry and poison the water supply for many communities.

Toward the center of the peninsula this freshwater lens is thickest, but near the coastline it quickly gives way to saltwater, developing anchialine cave systems along much of the coast, containing brackish or salt waters that rise and fall with the tides even with no direct open connection to the sea. Some systems do connect directly; in particular locales like Chan Cenote in Quintana Roo it is even possible to dive into a *cenote* surrounded by land and surface in the Caribbean Sea, or vice versa. Similar to the thickness of freshwater above saltwater, the depth of the top of freshwater lens from the ground surface is also critically important to water management. For example, the waters of the *cenotes* at Yaxuná are dozens of meters below the ground surface, and only accessible with stairs, ladders, and/or rope. At Cobá, some *cenotes* are similarly hard to access, while others contain water right at the edge of the ground surface, which slopes gently and easily to them. In the hilly Puuc region, its higher elevation excludes the existence of *cenotes*, and so inhabitants there dug cisterns known as *chultun* to collect and store rainwater to support their populations (Dunning 1994; Zapata Peraza 1989).

The Puuc region is sharply divided from the north along the Ticul Fault Zone, under which subterranean water flows west for the most part, while the neighboring region to the southeast flows further in that same direction from the long narrow Lake Chichankanab towards Bacalar and the east coast (Perry et al. 2003). As previously alluded, the Cenote Zone of the northwest channels underground water along the ring out to the Gulf of Mexico on either side, near Celestún and at Dzilam de Bravo. Just east of Cobá and expanding northeast is the Holbox Fracture Zone, which channels water towards the east and northeast coasts (Tulacyzk et al. 1993). Surrounded by the above hydrogeological regions and tucked into the central inland portion of the northern peninsula, sits the region of discussion, the Yaxuná-Cobá corridor, dotted with *cenotes* and *búuk'tun* (hummock-like rises of bedrock) but otherwise quite flat, with much of Cobá lying in a large depression including its lakes. Many of the *cenotes* in the region are closed-system, meaning they do not connect to others through subterranean passages (as do many along the east coast and in the northwest), although of course they do share the same aquifer which permeates their cave walls and thus the water table rises and falls fairly evenly in all *cenotes* in the area. The flow of water is also slower in this inland region, and the relatively isolated *cenotes* allow for the formation of greater numbers of *ts'aats'* and *ko'op*, discussed below.

4.3 Cultural and Archaeological Importance

Archaeologically, the above summarized geological/hydrological history of the Yucatán is important for a number of reasons. Foremost, the status of the ground surface above sea level or submerged logically dictated how early and widely the area could be settled by humans (or any other non-aquatic creature for that matter). Additionally, the existence, thickness, and distance from the surface of the aquifer was paramount for supporting life and later for determining the maximum carrying capacity for various species, including humans. During the Pleistocene and early Holocene, when the Yucatán was first occupied by humans (González et al. 2014), many currently underwater cave systems were mostly dry caves, and inhabited by a number of land mammals, including giant ground sloths. Paleoindians also utilized such caves - either for temporary shelter, semi-permanent dwellings, to hunt the creatures within, possibly for ritual activities, or all of the above. Recent discoveries also demonstrate how Paleoindians explored deep into caves to procure precious minerals, especially ochre (MacDonald et al. 2020). It is important to keep in mind is that these caves were not only mostly dry due to lower sea levels, but also much further inland when more of the Yucatán Shelf would have been exposed.

Such usage has changed greatly over time as many of those caves filled with water, and as Paleoindians and other early nomadic peoples gave way to (or themselves became) settled agricultural peoples by the start of the Middle Formative (Inomata et al. 2015). From the Paleoindian era we see glimpses of a difficult life; amongst the handful of skeletons recovered from this period there is evidence of cranial traumas, bacterial disease, and malnutrition (Chatters et al. 2014; Stinnesbeck et al. 2020), and the famous Naia may have met her end accidentally by falling in the depths of a dark cave. After water levels rose, *cenotes* were still important hunting/fishing grounds, for the fish, crustacea, turtles, birds, and caimans that live within or near them, as well as other land animals that would use the more accessible *cenotes* as watering holes. Classic Maya uses and cultural perspectives of caves and *cenotes* are discussed in more detail in the previous chapter, but they included ritual activities in the form of ceremonies and votive offerings, occasionally including human sacrifice (Price et al. 2019). By the Colonial Period, *cenotes* and caves were often used as refuges by the Maya in the face of brutal Spanish oppression and torture, and again similarly used as hideaways during the Caste Wars, for similar reasons (Munro and Melo Zurita 2011). They were most importantly used for their water supply through all of these periods, while their secondary and tertiary uses (and cultural importance) shifted.

Additionally, the water in *cenotes* and other water bodies can vary in terms of salinity, alkalinity, and levels of various minerals and elements, which will be discussed further in methodological considerations. Delgado and her colleagues (2010) classify the state of Yucatán into six different zones of water quality for purposes of modern agricultural irrigation based on concentrations of calcium and other minerals, effective salinity, and a number of other calculations. Their results include a swath of the best quality water running southeast of Mérida and notably covering Yaxuná and most of Sakbej 1 (Cobá is not included in their research area, being in the state of Quintana Roo).

The patterns of underground flow and seasonal precipitation also influence contamination levels of coliform bacteria, *salmonella*, and other pathogens. The rainy season is also known as "diarrhea season" (Marín and Perry 1994:622), as the constant rains wash more amounts of fecal matter, sewage, and industrial runoff into the aquifer. As recently as the 1970s, about 40% of deaths of children under 6 years of age were caused by such pathogens (Doehring and Butler 1974). Although modern industrial waste unquestionably contributes to this problem a great deal, coliform bacteria contamination and disease plagued the ancient Maya as well. Considering it appears to impact some regions and towns more than others due to underground flow of water and other hydrologic factors (Marín and Perry 1994; Pacheco A. et al. 2000), it is probable that the ancient Maya also noted the higher rates of disease in some areas and either shifted settlement strategies or developed methods to ameliorate the instances and severity of disease through localized water filtration and/or medicinal treatments. The focused flow of water along the more permeable Cenote Zone influences the hydrology of neighboring regions as well (Delgado et al. 2010; Marín and Perry 1994), and precluded significant settlement in a large swath of the southwestern portion of the ring (Rohrer 2012) due to the inability of *cenotes* in that area to "die" and become *rejolladas* or *ts'aats'*, discussed further below.

Use of cavernous landscape features also varies greatly depending on the type and nature of the feature in question. Caves, *cenotes*, and other such karst landscape features are not formed equally nor uniformly, naturally. Some *cenotes* do, more or less, fit the idealized notion of a collapsed doline or sinkhole with a large, fairly circular opening and vertical cylindrical walls leading down to a still pool of clear cold water. Many others, however, come in a great variety of shapes and sizes, with small openings to large caverns or vice versa, deep winding horizontal caves that eventually reach the water table in profound darkness, oblong or stretched amorphous openings that may not even contain water of any substantial quantity, or some combination of the above. Underground and underwater networks reside throughout the peninsula, with some *cenotes* as windows into that tunneled labyrinth, some which flow with a current out to sea and therefore contain a halocline with freshwater sitting atop the salty seawater layer. In fact, the peninsula is home to some of the longest and most extensive underwater cave networks in the world (Kambesis and Coke 2016). Finally, we should keep in mind the lifecycles of landscape features and how all of the above variables have themselves changed through time along with changes in climate and hydrology (van Hengstum et al. 2010). In the early 19th century, for example, an *aguada* in Jalal (west of Merida) went dry during a year of sparse rains, and the local inhabitants discovered several *chultun* and wells of varying depths when digging in the mud of its bed (Stephens 1843:149), indicating that the water table was significantly lower on average in that area in the past.

4.4 Yukatek Terms and Uses for Landscape/Waterscape Features

Some of the general forms or types of these differences in cavernous landscape features have specific names in Yukatek Maya. One of the most important distinctions is between a *cenote* (*ts'ono'ot*), a *dzadz* or *ts'aats'*, and a *rejollada* (*ko'op*). In a geologic sense, these type divisions can be understood as stages in the "life" of a solution cavern. Sinkholes form when acidic rainwater filters through fissures in the karst bedrock and erodes pockets of softer rock beneath the hard surface crust, a process dependent on a number of geologic and hydraulic variables (Dreybrodt et al. 2010). Over thousands of years, this process forms expansive underground cavernous spaces with only the thin surface crust hiding them from the open terrain and air. When that layer collapses, a new sinkhole is born. If it fully connects to the aquifer, it is dubbed a *cenote*. If they do not fully connect to the water table, which can happen immediately due to an abundance of collapsed rocky material, or slowly over centuries of soil accumulation and erosion, the solution cavern is more "mature," and is dubbed a *ts'aats'* if it is still swampy or wet at the bottom but not a substantial body of water (Houck 2004, 2006). Finally, as the cavern continues to erode and accumulate debris and soil, it may become a relatively shallow basin that is no longer wet year-round, known as *ko'op* in Yukatek but more commonly called a *rejollada*. *Rejolladas* may hold water in the rainy season, but they do not connect to the average yearly water table. Importantly, the metaphor of age or lifecycle for *cenotes*, *ts'aats'*, and *rejolladas* is a very loose one. If there is little erosion or sediment accumulation, or if a *cenote* connects to a flowing underground river which carries such sediment and organic matter away, then it may never "age" and progress toward a *rejollada*. Conversely, a sinkhole may very rapidly develop into a dry *rejollada* under contrasting conditions.

At the bottom (and usually in the center) of both *ts'aats'* and *rejolladas*, wells may be dug to allow easier and fuller access to fresh water. Precolombian retaining walls in *ts'aats'* (likely to stall the continued sediment accumulation and maintain water contact) are recorded at a number of sites (Houck 2006; Manahan et al. 2012). *Ts'aats'* and *rejolladas* are also both used (now and in past millennia) as prime locales for agriculture, especially trees whose roots can reach down through the limestone to eventually touch the water year-round even in the shallower *rejolladas*. In some cases, tree species with typically shallow root systems have shown the ability to extend their roots down into caves and cenotes (Adams et al. 2020), including palm (Sabal yapa). Moreover, the soil that accumulates in these depressions is usually excellent for farming, thus many *milpas* of a variety of crops are found within *ts'aats'* and *ko'op* today.

Cacao was perhaps the most valuable crop that would have flourished in many a *ts'aats'* and *ko'op*, as evidenced at several sites (Kepecs and Boucher 1996; Lentz et al. 2015; Munro-Stasiuk et al. 2014). The growing value of cacao may have lent some of these depressions to be connected with high status, and accordingly we often witness large elite complexes near *rejolladas* and *ts'aats'*. Cacao is prominently portrayed on friezes of the Initial Series of Chichén Itzá alongside carvings of jade, quetzal feathers, and other precious goods (Taube 1994; Taube et al. 2020), fitting companions considering its beans were used as currency (Kepecs and Boucher 1996:82; McAnany and Murata 2007:14; Millon 1955). This imagery is tied into K'awiil and other mythological imagery, but also represents the very real wealth of cacao grown out of the many *rejolladas* at Chichén Itzá, which helped that city rise to power (Osorio León 2006; Taube et al. 2020). At Cobá, two *ts'aats'* were tested for geochemical traces, and both contained evidence of cacao (León Romero 2016; Magnoni, Hutson, et al. 2016; Terry et al. 2022). One, Dzadz Iox, is located near the grand causeway termini complex of Kitamna, while the other to the south is more remote but still boasts monumental architecture on its western edge. Both of these *ts'aats'* figure prominently in the current research, as I ground surveyed these areas and performed test pit excavations nearby and within one, as further explored in Chapter 7.

Today, non-endemic fruit trees such as banana, citrus, and mango largely dominate most of these *rejollada* groves, though native trees are also found, such as *chi'* (nance), avocado, and chicozapote (Tripplett et al. 2007), as well as remnant cacao in sinkholes near Xocen and Yaxcaba (Gómez-Pompa et al. 1990). The soil in *rejolladas* is so rich relative to the otherwise inhospitable karst, that the Maya would also take such earth from the sinkholes for use in container gardening closer to their homes (Dunning and Beach 2010; Fedick and Morrison 2004; Folan 1983). In addition, *ch'ich'* mounds, or small piles of cobble, were and still are used to retain water and/or stabilize smaller trees (Kepecs and Boucher 1996).

There also exists a correlation between size and density of sinkholes and that of ancient edifices at some sites. The largest *rejollada* near the epicenter of Xuenkal rests in the shadow of that site's largest structure (Munro-Stasiuk et al. 2014). Ruins of Yalahau record a similar connection of structures with *cenotes* and *ts'aats'*, suggesting an elite control of preferred water sources with large openings and ease of access, perhaps to allow for public spectacle, whereas the *cenotes* of smaller communities more often were smaller and with narrower more restricted openings (Fedick and Morrison 2004). This connection is part of the stimulus for my research, to discover whether these differences in water sources were purely about ritual considerations and public spectacle (and aesthetics, imaginably) or if they also influenced the resilience of a community during drought.

Even with a single category there can be great variation. Some *cenotes* may be very difficult to access, their entrances found deep within *áaktun* (caves). Others may be easy to locate but only connect to the water table dozens of meters below the surface terrain with near-vertical rocky walls, necessitating ladders or ropes to access their freshwater pools. Still others hold water very near the surface, appearing almost as ponds or lakes at first glance, although they are usually much deeper and colder. Perhaps due to the dearth of lakes in the northern Yucatán (those in Cobá are rare exceptions), the common terms for them in contemporary Yukatek are *lago* or *laguna*, borrowed from the Spanish, but there are two indigenous terms for closed-basin water bodies (those disconnected from the aquifer that hold water due to a lining of clay and other non-permeable soils that prevent rainwater from percolating through the bedrock). *Áak'alche'* refers to a swampy area covered in small trees, and *chak'an* denotes a grassy plain that is seasonally flooded to become a pond or small lake but may remain a water body year-round during years of sufficient rains. However, in many Maya towns today words of Spanish origin are more commonly used for those features as well, *bajo* and *sabana*, respectively.

Another very important term and water feature in the *mayab* landscape is the *jaltun*, or *sarteneja*. A *jaltun* is a small shallow depression in hard outcroppings of the limestone bedrock, which collect and hold rainwater. Most are fairly small, no more than a meter in diameter, but they can range in size up to small ponds of about 15m long and are usually elongated and amorphous rather than the sinkholes which tend to be more vaguely circular. *Jaltun* are vital watering holes for many forest animals, and also used by hunters, farmers, or others with business in the area passing by or collecting wood or plants. In such case, these human handlers will clean the *jaltun* of any soil or sediment that has collected in their bases and will cover it with a flat rock top to prevent further accumulation of sediment, evaporation, and/or overuse from animals. *Jaltun* are not necessarily out in the wild (*k'áax*), they may also be in backyard patios or other domestic spaces, in which case they may more often be further modified with channels to encourage water collection. Accordingly, contemporary Maya use such domestic *jaltun* primarily as a water source for their domestic animals. Note also that *jaltun* are distinct from more formal built reservoirs or *akal*, and from larger natural *bajos*, swamps, and lakes.

Other limestone bedrock outcrops are composed of far softer material, a chalky substance known locally as *saskab*, hydrated limestone powder (calcarenite) found in large deposits of weathered marl that is often white but may also contain shades of light red and yellow (Littmann 1958). *Saskab* is used for a number of purposes, including as a tempering ingredient in most pottery (Thompson 1958), packed flooring material (especially in the Preclassic period), creation of limewater to soak maize, and for production of burnt lime plaster - a pervasive addition to the facades of most large precolombian Maya constructions (see Chapter 9). Tons of it was even used to help transform a humble sandbar into the island of Jaina (Benavides Castillo 2012; Cabadas-Báez et al. 2018; Piña Chan 1968). After excavating the *saskab* material, pits in the earth are left behind that are sometimes large enough to become anthropogenic caverns and depressions on the same scale as some *rejolladas*. Lake Cobá and Lake Macanxoc were each enlarged by such quarrying (Folan 1978), and many other pits and depressions at Cobá that fill with water during rains were also modified by quarrying and mining.

According to Folan (1983:24), over 200,000 m^3 of *saskab* and limestone were removed to form many *saskaberas* and quarries. Notably, a small well sits near the entrance of a large *saskabera* near central Cobá, with a low protective wall to prevent contamination (Folan 1978:80), a common feature at most significant *saskaberas* at Cobá. Apart from lime plaster, *saskab* is also simply added to building materials like mampostería and mixed with other materials and tamped down to create floors, the surface layer of *sakbej*, and at the bases of walls and stairs for consolidation. *Bajpéek*, a clay-like soil found in deposits near bedrock, is also used for such construction purposes. Palygorskite, or *sak lu'um*, may also have been added to lime plaster, in addition to its other uses as medicine, pottery temper, and ingredient in Maya blue pigment (Arnold et al. 2008; Arnold 1967).

Yukatek terms for other soil categories are also influential in water research, as they differentiate between soils that are commonly flooded - *áak'alche'* (refers to both the soil and the swamp in general, see above), those that are only flooded by heavy rains - *ya'ax kom*, as well as dark soils in humid conditions with decomposing organic matter usually found amongst mangroves - *pu'uc lu'um* (Bautista et al. 2012). Others speak to archaeological investigations directly; *kakab lu'um* refers to good soils with high phosphorus content found amongst archaeological remains, or what archaeologists call anthrosols. Most other Yukatek differentiations would fall into the category of leptosols in the typical Western pedological classification system, as such thin rocky leptosols cover about 80% of Yucatán (Bautista et al. 2012:66). Thus, the ethnopedology or "folk soil taxonomy" of the Maya is truly a soil science that surpasses Western taxonomy in many respects when it comes to the conditions of the Yucatán. It considers not only pedology but also edaphology, archaeology, hydrology, geology, topography, and other factors which have enabled farmers to succeed in that environment for millennia.

4.5 Conclusion

The above regional environmental specifics and peculiarities resulted in markedly different water management strategies for the northern Yucatán, which lacks the rivers important to many sites of the southern highlands Maya region. Lakes and *bajos* are also scarcer and smaller relative to southern regions like the Petén, though still important at sites like Cobá and Punta Laguna. In the succeeding chapter, I will discuss these differences, explain their importance to Maya chronological changes and resilience in the face of droughts and other climate changes, and detail the cultural histories of the sites around which this research is seated.

Chapter 5 Culture Histories and Maya Adaptations to Climate Change

5.1 Introduction

Cycles and trends in climate over time – especially that of long droughts or long intervals of heavy rainfall and flooding – have long been cited as primary causal factors for major demographic sociopolitical changes throughout the Maya region (Culbert 1973; Hoggarth et al. 2017; Iannone 2014; Kennett et al. 2012) and indeed throughout Mesoamerica and beyond, extending over much of the Americas in some cases (Goman et al. 2018; Schimmelmann et al. 2003; Stahle et al. 2011, 2016). Major droughts in the Maya area from roughly 800-1000AD, in particular, likely cemented the decline of Maya states that had already suffered from warfare and internal political strife, which thwarted the social recuperation typical of earlier epochs of Maya civilization (Douglas et al. 2016; Webster 2002). These debates can at times take on a "chicken or the egg" paradigm. Did droughts and other natural disasters and climatic changes disrupt Maya settlements to a boiling point and launch them over the edge into more caustic cultural behaviors like intensified warfare and stressful mass migration, or did the climate disasters strike a critical blow at a time when they were already strained? Most importantly to this research, there need not be one single definitive answer for every settlement in the whole of the Maya cultural region, nor even for more narrowly defined cultural or ecological zones. I plan to demonstrate that even relatively nearby settlements had varying degrees of resilience to these major climate crises. This chapter will review some important water management trends in diverse ecological zones of the Maya cultural sphere and general climate shifts through the Maya cultural epochs, and then look more closely at the cultural and environmental histories of sites along the Yaxuná-Cobá corridor, of which Cobá will be the primary focus.

5.2 History of Maya Water Management

Sophisticated water management techniques appear early in Mesoamerica. The Olmec of San Lorenzo Tenochtitlán (in what is now southeastern Veracruz state) constructed a 171m-long aqueduct line out of sections of basalt carved into half cylinders and capped with flat stones, fed by smaller drainage features (Cyphers 1999:162–165), all by 1000BC. A single-stage construction and singularly designed palace complex at El Palenque, Oaxaca boasts intricate water engineering, including cisterns, lined and lidded drains, *impluvia*, and a water shrine, initially built between 300-100BC, the Late Monte Albán I phase (Redmond and Spencer 2017), indicating an impressive state management of labor and construction. Centralized state management capable of large water management constructions like massive canals also emerged in some sites of the neighboring Maya region around the same time, most famously in the highlands of Guatemala at Kaminaljuyu beginning roughly 350BC at the onset of the Providencia phase (Arroyo et al. 2020; Arroyo and Henderson 2019; Inomata et al. 2014).

While scholars have noted that many prominent sites in the northern Yucatán peninsula did not really begin to burgeon until the Late Classic, some enjoying most of their fluorescence during the Terminal Classic period (a time when many major sites of Petén and other southern regions had already been largely abandoned), more recent research indicates that the northern Maya lowlands has a long history of urbanization starting in the Preclassic (Stanton 2012), demonstrated at sites like Yaxuná (Stanton

2017), Dzibilchaltún (Andrews 1960), Xocnaceh (Gallareta Negrón 2018), Komchen (Ringle and Andrews 1988), Xtobo (Anderson 2011), and Edzná, the last of which boasted a Preclassic hydraulic system including canals (Matheny 1976).

Historically, however, the highlands and coasts of southern Guatemala and Chiapas were often given primacy as a place of origin for Maya culture. This may be in part due to the strong influence of the Kaqchikel and K'iche' at the time of Spanish conquest and afterward, but perhaps more owed to early excavations in the highlands and the discovery of Preclassic carved monuments at places like Takalik Abaj. Additionally, Barra phase ceramics of Soconusco, Chiapas date to as early as 1900BC, amongst the earliest in Mesoamerica (Joyce and Henderson 2001; Rosenswig 2012). However, we now understand that the origins and development of Maya society are more complex. In addition to the early northern lowland sites mentioned above, some foundational features of Maya society (e.g., early agriculture) appear to have originated in the swampy southern lowlands of the Petén, and recent discoveries in Tabasco push back the earliest known monumental platforms in the region to 1000BC at Aguada Fénix (Inomata et al. 2020). Nevertheless, many early Maya cultural markers have their earliest known appearances in the highlands, including iconographic links between Olmec and Preclassic Maya art (Taube 1995a). Furthermore, sites from the southern highlands such as Izapa, Takalik Abaj, and Kaminaljuyu are amongst the earliest Maya permanent settlements with stone architecture. All three of these also demonstrate remarkable and remarkably early water management features of the Preclassic Maya.

The labor of Takalik Abaj denizens produced a water drainage system as early as the Middle Preclassic (Marroquín 2005). The water was channeled – via at least 25 small canals –into residential groups rather than to agricultural fields, though the water likely supported house-lot gardens. The initial impetus for the construction of such channels may have principally been to drain water away from certain structures rather than provide water to others. In their earliest incarnations of the Middle Preclassic, these mini canals were simple clay conduits, but were upgraded to stonework channels by the Late Preclassic and on through the Classic, when the largest stonework channels at Takalik Abaj were built. The original clay earthwork channels were already an indication of a high level of planning and organization of labor at Takalik Abaj, and the addition of stone further emphasizes the degree of site planning considerations at the site in a way that even monumental architecture itself does not necessarily express. The situating of monumental architecture atop a series of terraces is likewise indicative of sophisticated site planning by doubling as water management features (Schieber de Lavarreda and Pérez 2004).

A *píib naj* (sweat bath structure) with subterranean drainage has also been documented at the site, an erudite and important bit of engineering for elite occupation. The smaller site of Chocolá, about 35km east of Takalik Abaj, sports similar terracing and water channels (Kaplan 2008). By the Late Classic, however, fragments of stelae at Takalik Abaj were repurposed as construction material for some of these waterworks, signifying a transformation in the social order, and possibly in the manner and style of state organization.

Kaminaljuyu undertook even grander water management constructions in the Preclassic. Situated around Lake Miraflores, laborers at Kaminaljuyu constructed massive canals to irrigate fields to the south of the lake. The earliest documented canal, dubbed the Miraflores Canal, was about 1km long and dug in the Middle Preclassic (Valdés 2006). By the Late Preclassic, it was abandoned and used as a trash pit, in favor of two newer and more sophisticated canals which better regulated the flow of water into smaller irrigation channels, rather than simply providing controlled flooding. A network of smaller canals that flooded plazas and surrounded mounds may also have served as irrigators of gardens or orchards, but, perhaps more importantly, they point to an early sophisticated urban planning model for aesthetic and ritual purposes beyond the mere functional (Arroyo and Henderson 2019). Other canals and reservoirs further underscore a centralized authority and organizational system, and early monuments and royal tombs also appear here at Kaminaljuyu, as at Takalik Abaj, its contemporary trade partner.

Scarborough (2006) dubs the type of water management features and strategy at Kaminaljuyu as “Perennial Lake Management,” and links it to compact settlement. Though initially highly successful and likely the primary contributing factor toward the economic and political supremacy of Kaminaljuyu over the region in the Late Preclassic, this achievement also serves as a warning in long-term sustainability, as these grand canals appear to have contributed to the drying up of the now extinct Lake Miraflores, along with major droughts at the end of the Preclassic (Velez et al. 2011). Importantly, the lake appears not to have dried completely at the end of the Preclassic, nor even until relatively recently in the eighteenth century (Arroyo and Henderson 2019). Nevertheless, despite adaptative strategies toward canal construction and intensified ritual activity, Lake Miraflores was severely depleted by the Early Classic. Understandably, these droughts and the loss of their primary water source devastated agricultural production at Kaminaljuyu and thus weakened its economic domination, which lead to political destabilization and perhaps opened the doors for dominance from Teotihuacan (Valdés 2006:77).

Coring from nearby extant Lake Amatitlán supports a general decline in agriculture around this time (Lohse et al. 2018; Velez et al. 2011), and vitally records that, in most cases, substantial volcanic activity in the region does not appear to correspond with agricultural and demographic shifts, leaving drought and anthropogenic factors as more likely culprits. This new environmental, demographic, and political paradigm at Kaminaljuyu by the Early Classic resulted in a more sprawling agricultural distribution and settlement. Notably, recent work on ceramic and architectural sequencing at Kaminaljuyu has shifted much of the chronology of the site forward by about 300 years from previous consensus (Arroyo et al. 2020; Inomata et al. 2014), but this mainly serves to reinforce the above discussion and make better sense and correlations between the archaeological and geological/environmental pools of data.

Further north, in the Southern Lowlands, sits the Petén Basin, so called for the many *petén* (islands) in the region, marshy areas with woody vegetation as a result of freshwater upwelling from holes in the karst bedrock. These *petén* and *bajos* were ideal for early agriculture and settlement, providing ample water and ease of transportation (Cooke 1931:286). El Tintal, settled extensively and intensively in the Preclassic and connected to El Mirador, is a particularly excellent example of early water management in the region. The bulk of its settlement was built around a large depression that is now a mere *bajo* known as El Juleque, but during the wetter Preclassic would have been a far more imposing water body, dubbed Chacamat Lagoon by Acuña and Chiriboga (2019). The western end of this former lake features terraces that may have functioned as docks for canoes (Acuña and Chiriboga 2019), while core settlement off its southeastern shore is surrounded by a canal system reminiscent of a grand moat known as the perimetric canal (López 2015; López and Schreiner 2014).

Yet some imposing ancient centers of Petén, like Tikal, seem purposefully and irrationally built away from easy access to fresh water sources that would have made everyday life easier. Remnant springs at Tikal (Scarborough et al. 2012) may explain its already impressive settlement in the Late Preclassic, though at that time it was overshadowed by El Mirador, El Tintal, Nakbé, and other sites to the north. However, with the drying at the end of the Preclassic, the emergence, growth, and development of Classic Maya cities in the Petén and greater Southern Lowlands was often primarily facilitated by water reservoirs, which were typically built into elevated areas. These reservoirs provided year-round water in many areas where seasonal rainfall was abundant but insufficient to support urban populations through the dry season, particularly at Tikal, which also boasted sustainable land use and a sophisticated water management system including a large dam, cofferdam, sand filtration (Scarborough et al. 2012), and even the recent discovery of a zeolite water purification filtration system (Tankersley et al. 2020), all of which enabled Tikal to thrive for centuries as a large prosperous urban center.

Moreover, Tikal's water management system is clear evidence of state organization and centralized political control (Scarborough 1993). The distribution of reservoirs and other water features, expanding outward from the epicenter of Tikal, indicates elite centralized organization at that site, but not all urban reservoirs and water features were a product of state or elite centralized authority. At Caracol, large reservoirs connected to the *sakbej* road system are likely a product of elite control (Chase and Chase 2001), but smaller reservoirs associated with residential groups or terraces suggest a “vernacular agricultural and domestic landscape that is constructed and maintained at the household level” (Crandall 2009:42), despite a high uniformity of construction methods. In other words, these small household reservoirs did not depend on corvée labor or other help beyond the group it served, whereas large reservoirs necessitated the organization of a larger labor force, and thus were likely orchestrated by the state and used as ordained by those in power.

Still further north, but still in the Southern Lowlands of what is now the state of Campeche, Mexico, the site of Becan was dubbed by Ruppert and Denison (1942:54) to mean "water-filled ditch/ravine" after its imposing ring of ditches, although they do not hold substantial water and were more likely a dry fortification feature (Webster and Ball 2021), while also serving other purposes over time. This ring effectively encircles the central core of monumental architecture at Becan. It may have served defensive purposes for incursions during warfare; it certainly restricted access to the core area. Additionally, a network of raised linear features built of earth and stone, or ridges, likely served both as walkways (Thomas Jr. 1981; Turner II 1974:101, 1983:91) and as berms to block wind and retain soil and water for agricultural purposes (Turner II 1983:91). These ridges greatly resemble the *chichbes* of Chunchucmil, Cobá, and other sites, a key feature which I discuss in greater depth in later chapters.

Of course, not all ancient Maya lived in large cities. In the swampy *bajo* ecosystems of the Southern Lowlands, agricultural practices often revolved around local household organization, both through kitchen gardens and intensive field cultivation of staple crops like maize, where there were "decreasing amounts of labor in cultivation as the distance from house to agricultural field increased" (Kunen 2004:98). Water management systems also often operated at such a localized household level. For example, a residential house-lot group near Dos Hombres, Belize, modified the limestone bedrock to drain excess surface and subsurface water through heavy rains, while also employing lithic mulching to slow evaporation and moisture loss during the dry season (Lohse and Findlay 2000). Likewise, Brewer (2018) found that small depressions - both nonanthropogenic and former quarries - were operated and maintained at a local household level both at the small hinterland site of Medicinal Trail and at the urban center of Yaxnohcah. Clearly, state organization was not a requirement to manage water supplies in small communities.

Whether state or community organized, reservoirs, *bajos,* and small depressions were also tremendously important for the demographic changes and increases of the Classic period. Many *bajos*, *aguadas*, and small lakes were infilled or otherwise altered over time through such practices as flood recession agriculture, indicated by berms and terraces near the margins of *bajos* (Kunen 2004). These alterations to the landscape sometimes backfired and eventually led to degradation or loss of small water systems, necessitating changes in agricultural and water management practices. Thus, Scarborough (2006:229) posits a model wherein the Maya "moved from a concave *bajo* microwatershed adaptation to a convex 'water mountain' microwatershed during the Classic period." In this paradigm, one of the foremost characteristics of the transition from the Preclassic to Classic is the transformation of water management strategies and technologies, catalyzed by largely anthropogenic local environmental and ecological changes. "Probably induced by deforestation as a result of population growth and immigration, soil loss from surrounding lake-margin slopes excited by extensive slash-and-burn activity forced a different settlement design" (Scarborough 2006:230). This new settlement design of elevated reservoirs, then, may have emerged as a response to failed or stressed agricultural systems stemming from population pressure.

Major centers in the Petén like Yaxha are increasingly blamed, at least partially, for their own downfalls by way of environmental destruction or environmental stress combined with natural climate change pressures (Turner and Sabloff 2012). Through the beginnings of Maya history to the end of the Classic Period, rural populations doubled about every 400 years in the Yaxha-Sacnab basin (Rice and Rice 1990). Pollen data and soil analysis indicate the Maya deforested the area around their urban centers and construction altered the soil, and therefore, the productivity of the crops (Deevey et al. 1979).

In other cases, accidental (or at least incidental) anthropogenic alterations to the landscape were perhaps less harmful. While Gunn and colleagues (2011) admit that heavy erosion in parts of their research area in the Laguna de Términos and Río Candelaria drainage areas were caused by ancient Maya agricultural practices and perhaps deforestation for lime production, they also note that the Maya seem to have somehow mitigated erosion in some instances and overcame periodic climate disruptions, at least until they were too intense to sustain, as were the droughts of the ninth century AD. Indeed, the initial slumping of calcium-rich soils from the uplands down onto the edges of the *bajos* appears to have been a major spark for agricultural intensification and larger populations in the first place at sites like Calakmul (Gunn, Foss, et al. 2002). All of this is not to fall into the same pitfall of water-based environmental determinism of Wittfogel, as this same pattern did not occur evenly or universally throughout the Maya region, even in very similar environmental niches. However, as Scarborough (2006:230) succinctly states, "environments make a cultural difference."

Indeed, stark contrasts in environment and geography often mirror cultural divides. In the Northern Lowlands, the Puuc region is the clearest example of this, where its rolling hills and higher elevation relative to the very flat shelf to its north and east lead the inhabitants of the region to largely depend on *chultun* for drinking water in a land with almost no *cenotes* and very few water bodies in general (McAnany 1990). While *chultun* exist elsewhere in the Maya world, in some cases they were for food storage (Puleston 1971) and/or burials in addition to or instead of cisterns, while in the Puuc they are virtually always utilized as cisterns and are found with much greater frequency and density. In addition to this particular water management strategy and environmental lay, the Maya of the Puuc developed other distinctive cultural markers, including a finely crafted slate ware ceramics (Smyth, Dore, Neff, et al. 1995), and splendid architectural styles that greatly enthralled some of the earliest explorers and archaeologists to visit them (Proskouriakoff 1946; Stephens 1843), and continues to astound visitors today.

The fault line that delineates the northern Puuc border did not completely delimit this cultural style, though. Puuc architecture configurations made their way further afield as influence spread; Yaxuná, for example, showcases a prominent "Puuc group" built in the eighth century AD (Novelo Rincón 2012), indicating the strong cultural influence and reach of the Puuc at that time. On that note, I will discuss the cultural histories of Yaxuná, Cobá, and a few sites along the grand causeway that connects them.

5.3 Culture and Environment Histories

There have been several projects at Yaxuná, including the Carnegie Maya (Weeks and Hill 2006), the Selz Foundation Yaxuná Project (Stanton et al. 2010), the Instituto Nacional de Antropología e Historia (INAH) (Toscano Hernández et al. 1999; Toscano Hernández and Ortegón Zapata 2003), and the Proyecto de Interacción Política del Centro de Yucatán (PIPCY) (Stanton and Magnoni 2008, 2009), but they have not specifically focused their gaze on issues of water management and water resources. Donald Slater (2014) analyzed caves and *cenotes* at Yaxuná and the Yaxcabá region for evidence of elite ideological control of caves in hinterland or remote areas, but this research focused predominantly on ritual and cosmological significance of caves rather than management of the water resources within them.

Ceramic data from Yaxuná indicate it was settled by the early Middle Formative, when it became an important northern center with ties to the distant Petén and continued to develop throughout the Late Formative with the expansion of its E-Group (Freidel and Suhler 1995; Stanton and Collins 2021, 2017; Stanton 2012; Stanton, Dzul Góngora, et al. 2023; Stanton et al. 2010; Stanton and Ardren 2005; Suhler et al. 1998; Tiesler et al. 2017). Ceramic distribution, architecture, and settlement patterns at Yaxuná indicate a significant demographic and political decline at the end of the Formative, leading to a reduced population and altered social organization through the Early Classic (Stanton 2000). Such social and political changes were similar through this transitional period in other regions of the northern Yucatán as well (Glover and Stanton 2010), setting the stage for a Classic Period marked by increased social stratification and regional clustering of ceramic styles, burial traditions, architectural styles, and other material culture. Eventually, like many other Maya urban centers, Yaxuná fell into decline in the Terminal Classic. Despite the erection of defensive walls in that era, Yaxuná appears to have been sacked and razed around the turn of the tenth century AD by the forces of Chichén Itzá, who enacted desecratory terminations to important structures and annihilated the local leadership (Ambrosino 2007; Ambrosino et al. 2003). After this, the population of Itzá-ruled Yaxuná appears reduced in size and the city never recovered its former glory, with little to no occupation by the Late Postclassic, despite some ritual activity there (Ardren 2003). The contemporary town of Yaxuná was re-founded in the early twentieth century, and today some 800 indigenous Maya live nearby the ancient epicenter.

Before this, in the Late Classic, Yaxuná was connected to the burgeoning city of Cobá in the seventh century AD by the longest known ancient causeway in the Maya region, known as Sacbé 1 (Andrews and Robles Castellanos 1985; Benavides Castillo

1981a; Freidel 1992a; Loya González and Stanton 2013, 2014; Stanton, Ardren, et al. 2020; Stanton, Magnoni, et al. 2020). Alfonso Villa Rojas (1934) launched an expedition to walk and map the entire length of the *sacbé* in 1933 with a crew of twelve men plus himself, who were likely the first to fully do so in several centuries. Though he recorded a handful of sites along the way, subsequent archaeological research has been very limited in this important region between Yaxuná and Cobá.

Juan Peón Contreras led the first modern expedition to rediscover the city of Cobá in 1882. His report and sketches inspired other explorers such as Teobert Maler, who took the first known photographs of the site in 1891. Charles Lindbergh flew over the area in 1929 and noted "two green eyes" (Bennett 1930:347), the two largest lakes of Cobá, but he and other pilots of that era were unable to spy the *sakbej* and large structures covered in dense jungle. After other early Carnegie Institute expeditions at Cobá (Andrews 1938; Bennett 1930, 1931; Coe and Coe 1949; Thompson et al. 1932; see Weeks and Hill 2006 for a more complete list), work at Cobá has been ongoing since the early 1970s (Benavides Castillo 1976b, 1981a; Con Uribe and Esparza Olguín 2017; Con Uribe and Gómez Cobá 2008; Folan 1977; Folan et al. 1983, 2009; Folan and Stuart 1977; Gallareta Negrón 1981, 1984; Garduño Argueta 1979; Manzanilla and Barba 1990; Navarrete et al. 1979), but the bulk of this work has focused on mapping and restoration of major structures. The maps generated from these efforts helped to create a sense of the spatial patterns of intersite causeways and monumental architecture, as well as domestic settlement at Cobá.

The inhabitants of Cobá benefited from several small lakes (known now as lakes Cobá, Macanxoc, Xkanhá, Sacakal, and Sacalpuc) in a low-lying area around which the site developed, but *cenotes* also played a large role in providing water, along with cultural strategies for ensuring the potability and/or viability of water for agricultural use. Early work at Cobá (Folan et al. 1983:34) initially noted dikes surrounding both Lake Cobá and Lake Macanxoc, "check dams crisscrossing almost the entire city," catchment basins, *sascaberas,* and limestone quarries. These check dams are rarely mentioned again, but I suspect they refer to what we have labeled *chichbe* (see Chapter 6). Since then, little additional work on water management has been conducted at this site, despite its prime lakeside location and massive size. Cobá is often considered primarily a lake city, but this research documents and highlights the importance of *cenotes* and other features in the water management of this city, which have been overlooked.

Regions neighboring Cobá, like Yalahau to its northeast and Cochuah to its southwest, have witnessed more water management research. Yalahau is dominated by a freshwater wetland ecosystem, leading Scott Fedick and others (Chmilar 2013; Fedick 2014; Fedick et al. 2000; Fedick and Morrison 2004; Fedick and Taube 1995; Leonard et al. 2019; Leonard 2013; McKay et al. 2020; Wollwage et al. 2012) to apply environmental approaches and paleolimnology to their research there. The size and density of *cenotes* and *ts'aats'* in Yalahau correlated directly with structure size, with smaller settlements and structures utilizing smaller cenotes with narrower openings (Fedick and Morrison 2004:210). This pattern further indicates elite control over preferred water sources. However, this does not mean Yalahau commoners were cut off from direct access to water. The topographic proximity to the water table allowed for ease of the construction (or modification) of *ch'e'en*, and indeed a number of ancient wells were found at Naranjal and other Yalahau sites (Winzler and Fedick 1995). Notably, numerous impressive megalithic structures at Naranjal (Taube 1995b) mark it as an important and powerful center from roughly 100-450AD, confirmed by ceramic analyses.

Further afield from urban centers at Yalahau, amongst the swampy wetlands for which the region is known, are many anthropogenic rock alignments constructed in order to manage these wetlands for agricultural ends (Chmilar 2013; Fedick et al. 2000; Leonard et al. 2019). These alignments essentially acted as berms to accumulate soil and manage rain runoff and floodwaters, allowing their builders to grow crops through the dry season in some wetland areas (Leonard et al. 2019). Similar rock alignments (or linear features) exist at Cobá, and I propose many were utilized in somewhat the same manner, on which I will elaborate in Chapters 7-9. However, most of the linear features at Cobá were ostensibly built later than those of Yalahau.

Yalahau was largely abandoned by the early fifth century AD (Wollwage et al. 2012) due to rising sea levels and saltwater intrusion that disturbed the freshwater lens (Aragón-Moreno et al. 2012; Bauer-Gottwein et al. 2011; McKay et al. 2020) and disrupted agricultural production in that region. The Early Classic Yalahau abandonment also coincides with a time when Cobá rose greatly in population and political influence at the start of the Late Classic (Fedick 2014; Folan et al. 1983). Specifically, Cobá witnessed a great demographic bloom during the Palmas Complex, ca. 550-730AD

(Robles Castellanos 1990; Stanton et al. 2024), with this ceramic material heavily dominating most excavations to date at Cobá. Sacbe 1, in total a feat of labor greater than any single temple at Cobá, also dates to the Palmas Complex (Ardren 2003; Loya González 2008; Loya González and Stanton 2013; Stanton et al. 2010; Tiesler et al. 2017:36–40).

Sediment cores from Lake Cobá (Leyden et al. 1998; Whitmore et al. 1996) support and add to the culture history of Cobá, indicating forest clearance as early as 1650BC, maize agriculture by 850BC, and the diking of Lake Cobá around 720AD, around the end of the Palmas Complex when population and urbanization at Cobá would have been at its height, along with its political and economic prominence in the region. However, merely sixty years later, 780AD, a sculptor carved the last known monument date at Cobá, and the sharp decline of said political prominence followed not long after. Lake Macanxoc was likewise heavily modified, with culverts connecting lakes and canals perhaps creating others, and this central lake area of Cobá is dense with *sascaberas*. However, no large-scale agricultural constructions like those at Yalahau have been identified at Cobá, leading Folan and his colleagues (1983) to promote an urban garden model at the site.

The water levels at Cobá can vary wildly from season to season and year to year dependent upon rainfall. This is the case throughout the Yucatán, but more pronounced at the low-lying city of Cobá with its closed-basin lakes. Some early explorers of the late nineteenth century noted island mounds in the lakes, whereas others in succeeding years missed them, likely due to visiting during times of higher water levels (Folan 1983:3).

The Cobá *sakbej* network itself is a water management feature, in part. Some cut directly through lakes Cobá and Macanxoc, and *áakalche'*, acting both as bridges and dikes, to compliment the dike earthworks about the larger lakes (Folan 1989; Folan and Stuart 1977). Most of the *sakbej* traverse low-lying areas prone to flooding for most of their courses, before reaching their termini groups built upon ridges above the flood-prone zone. Smaller *sakbej* (some with ramps) and other linear features also lead to/from lakes, *cenotes*, and other small water bodies including remnant *saskaberas* (Folan and Stuart 1977). Furthermore, many architectural groups at Cobá had at least one small reservoir or catch basin, and the city was dotted with check dams (Folan et al. 1983:34) to help control the flow of water during heavy rains.

The royal history of Cobá is particularly fascinating for a number of reasons. Cobá boasts more stelae (found primarily in the Macanxoc group) than any other site north of Calakmul, and, despite heavy erosion to many of these stelae and other carved monuments, the vestiges record one of the few relatively well-documented Classic Maya dynasties of the far northern Yucatán. More remarkably, female rulers figure prominently in these records. Tatiana Proskouriakoff (1961) first noticed that the majority of the central figures of the Macanxoc stelae are indeed women, queens rather than kings. Furthermore, they appear to mostly be designated as *kaloomte'*, the grandest Maya title, connoting a ruler more on the level of an emperor or high queen/king.

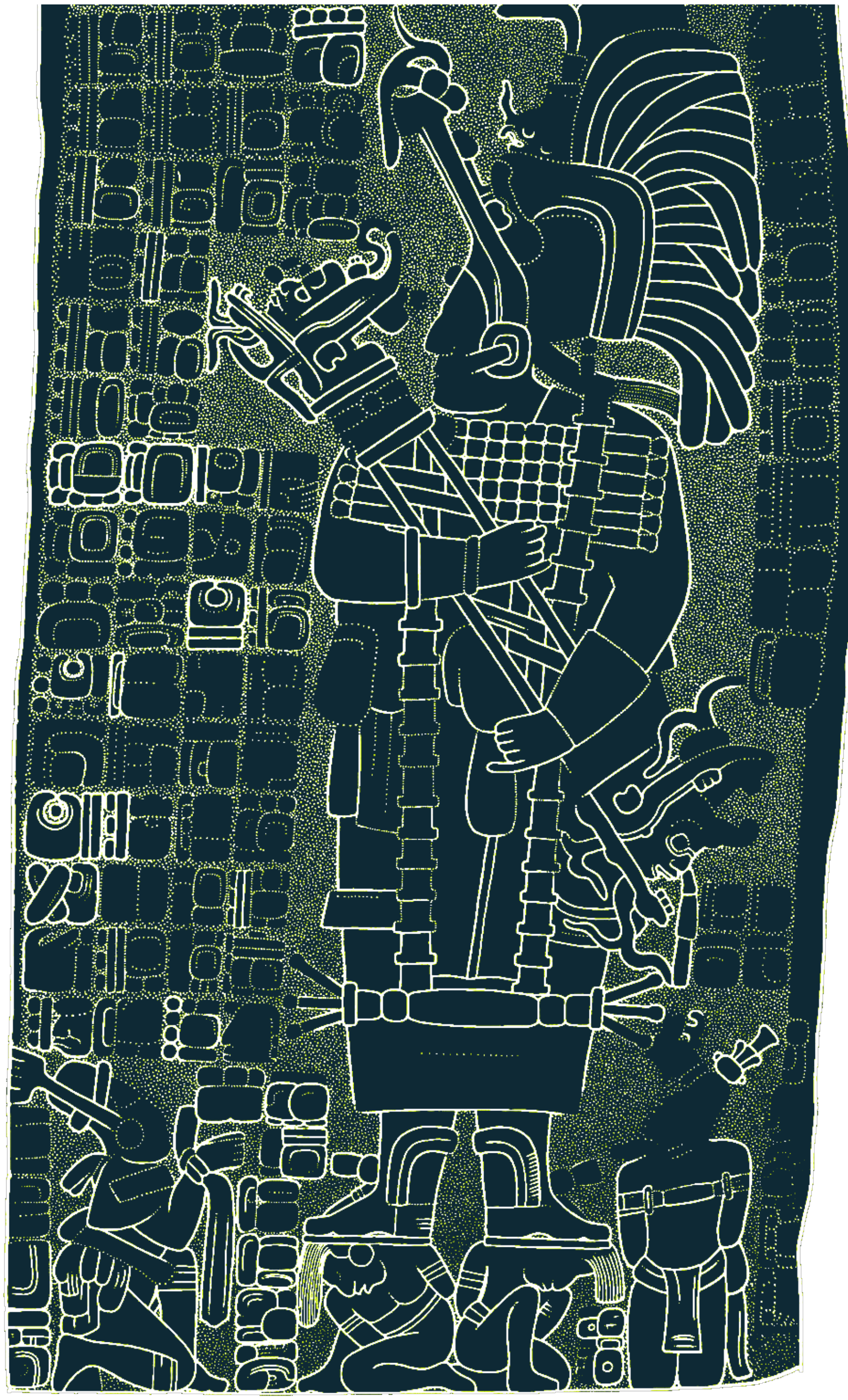

Figure 5.1 Coba Stela 1 (back/west side), depicting Lady K'awiil Ajaw. Colorized interpretation after a drawing by Graham and von Euw (1997:8:22).

Building on those early findings by Proskouriakoff (1961) and others (e.g., Thompson et al. 1932), and more recent efforts by Stuart (2010) and Gronemeyer (2004), Stanley

Guenter (2014) proposes that perhaps the most prominently portrayed ruler of these stelae (appearing on at least four) is a *kaloomte'* dubbed Lady K'awiil Ajaw, who ruled from 640-681AD and probably presided over the construction of most or all of Sacbe 1, in addition to other great works of Cobá (such as some of the stelae themselves).

The founder of the dynasty, around 500AD, may have also been a woman *kaloomte'* and likely ancestor of Lady K'awiil Ajaw, perhaps even bearing the same name (Guenter 2014), although more recently Octavio Esparza Olguín (2020:100–101) has interpreted the eroded glyphs of Panel 7 to read Ju'npik Tok' as the name of this early founder. About a century after the death of Lady K'awiil, the last known ruler by the name of Chan K'inich celebrated a half-*katun* ending on 9.17.10.0.0, 12 Ahau 8 Pax (November 26, 780AD), leaving behind this last known date recorded by the dynasty of Cobá, carved into Stela 20.

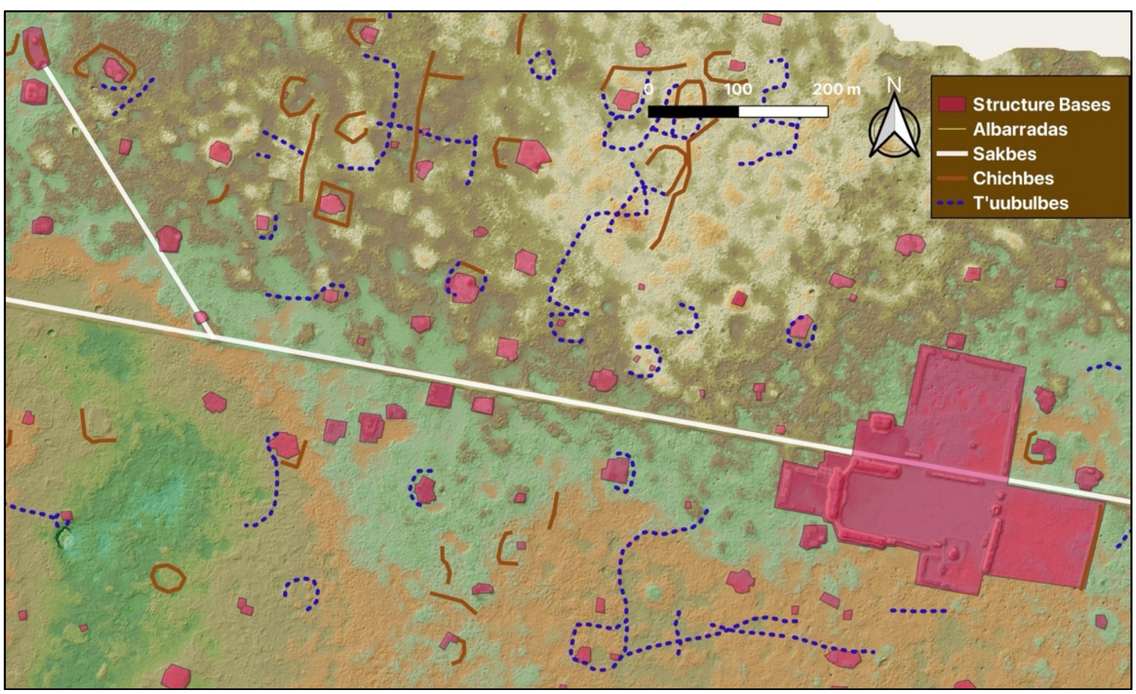

Figure 5.2 Lidar map of Oxkindzonot along Sakbej 1.

Along Sacbe 1 between Yaxuná and Cobá lie a number of smaller yet important sites, including Ekal, Kauan, and Oxkindzonot. Early explorers of the 1930s have traversed part (Bennett 1930, 1931) or all (Villa Rojas 1934) of Sacbe 1, but culture histories of these roadside towns are largely uninvestigated and remain an exciting area for future research. Several of these sites display architecture in conjunction and alignment with the *sakbej*, especially those closer to Cobá, like Oxkindzonot (Figure 5.2), which may indeed be considered within the boundaries of Cobá to its western extent (Stanton, Ardren, et al. 2020; Stanton et al. 2024).

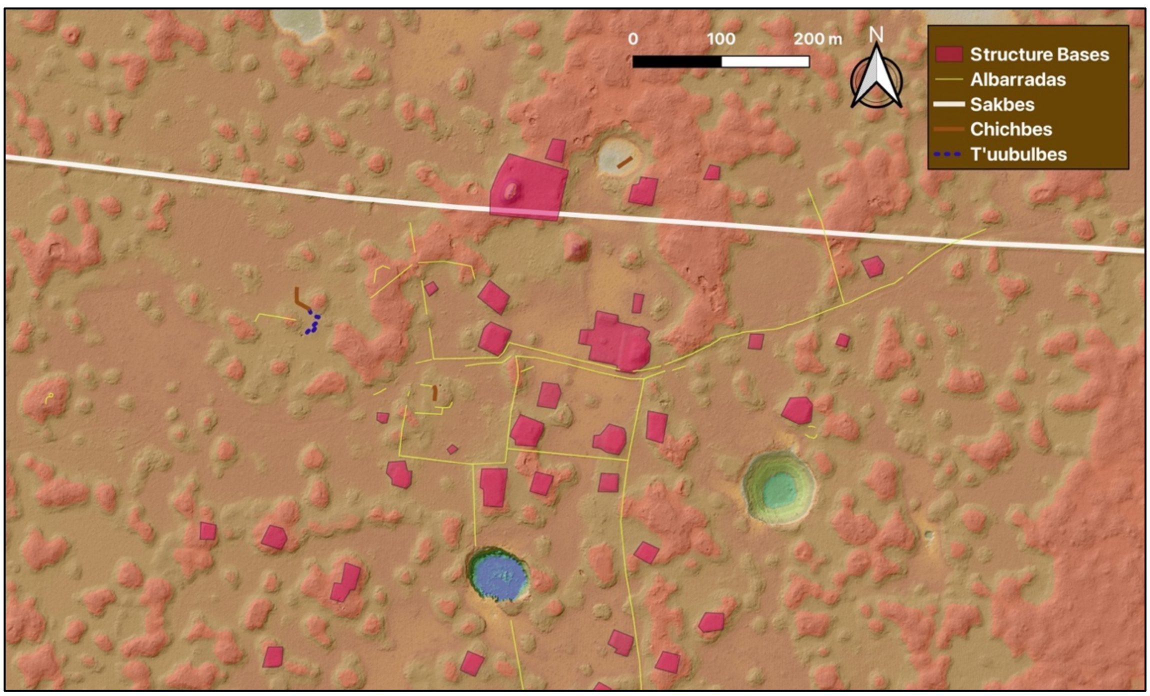

Figure 5.3 Lidar map of Ekal along Sakbej 1.

Others show clear signs of later construction and occupation after regular use of Sacbé 1 in full had ceased, as material from it was robbed to build structures nearby or directly in its former path, as at Ekal (Figure 5.3). The tendency of this grand *sakbej* to have been built straighter and wider as it approaches Cobá, along with tighter architectural alignments on that end, while curvier or more winding sections with less explicit structure-to-road orientation appear in the middle and western half, provides more evidence that Cobá was the dominant political power at this time, and the initiator and primary patron of the construction of Sacbe 1. Taking on this massive construction helped connect Cobá to other sites, facilitated trade, and promoted its political might to overshadow other major polities in the region at the time like Ek' Balam (Houck 2004).

Given this regional, cultural, and historical context, urban and rural communities along the Yaxuná-Cobá corridor emerge as excellent case studies for resilience, comparing water management and sustainability strategies within and between these communities. This will allow us to determine the role of water management and adaptation to climate change in political integration and urbanization processes, while also appreciating the cosmological importance of water sources toward the settlement of cities and communities.

5.4 Climate Change and Major Droughts

Droughts are not altogether uncommon in some parts of the Maya cultural region, but it is the length and severity of a drought that causes major problems. In a sense, the dry season in much of Mayab can be considered an annual drought, and both dry and wet seasons can vary drastically from year to year in their bounty of rainfall. Rain pours as I write this in Valladolid, Yucatán in January 2021, the height of the dry season, and has done so many of the past days. Last summer and rainy season of 2020, a number of hurricanes dumped too much water too rapidly on much of the Yucatán, causing flooding in many towns and milpas, including at Yaxuná. However, occasional hurricanes are not always necessarily maladaptive, as their destructive forces can help clear forest land for the milpa cycle (Sánchez-Sánchez et al. 2015). The year before (2019), the rains were slow in coming and Lake Cobá sat very low while *ejiditarios* worried about the state of their crops. Another year before, in summer of 2018, the rains came early and would not cease, pausing excavation work and flooding the tourist parking lot at Cobá. Clearly, this yearly variation can create minor disasters, but these hurdles can be overcome relatively easily. If, however, this back-and-forth variance switches to either heavy floods and hurricanes or long dry spells for multiple years on end, that becomes a major crisis.

Such crises have occurred several times throughout Maya history, with varying impact on the major urban centers of this civilization. One of the best and most thorough treatments of drought history of the region is to be found in the edited volume "Great Maya Droughts in Cultural Context" (Iannone 2014). This book was a great resource in preparing my current research strategy, but it mainly focuses on the Central Lowlands, with only passing mentions to sites in the Northern Yucatán. I want to help give a similar treatment to the Northern Yucatán by adding more research about the response to major droughts or other climate changes at sites along the Yaxuná-Cobá corridor. We must of course acknowledge that not only is the climate very distinct between the Southern and Northern Lowlands, but also between this central corridor of the north and neighboring areas like the wetlands of Yalahau, or the much drier northwestern corner of the peninsula around Mérida. Zooming in still further, I look at the influence of microclimates and whether the number, sizes, and types of lakes, *cenotes*, *rejolladas*, and other such features relative to the size and density of settlement had a measurable impact on the resilience of those settlements during climate crises like major droughts.

To date, the preponderance of evidence indicates a relatively wetter climate throughout the Maya region during the Late Formative, a drier environment through most of the Classic Period, and major droughts during the Terminal Classic, which were most severe in the Northern Yucatán, as seen in environmental reconstructions from Lake Chichankanab (Evans et al. 2018), Punta Laguna (Curtis et al. 1996; Hodell et al. 2007), Pac Chen (Krywy-Janzen et al. 2019), Yok Balum, Tecoh Cave (Medina-Elizalde et al. 2010), and comparative analyses of the above and more (Douglas et al. 2015; Hunter et al. 2019; Kennett et al. 2012). These droughts began in the early ninth century AD but became much more severe by the end of that century and were to continue off and on with some severity until around 1100AD.

Of course, there was not a constant unending drought spanning these three centuries, but considerable amounts of rainfall during years and spans of greater precipitation may have come from hurricanes and tropical storms (Sullivan et al. 2022), which would only compound the difficulties of agricultural efforts with "flash floods" (creating temporary streams and chasms) and/or insufficiently consistent rains throughout the rainy season (Medina-Elizalde, Polanco-Martínez, et al. 2016). Additional decades of dry periods occurred during the Postclassic in the mid-twelfth century, late fourteenth century, and around the time of conquest, though these droughts may have been more severe in Oaxaca, Central Mexico, and the Southwestern USA than they were in the Northern Yucatán and the rest of the Maya realm (Goman et al. 2018; Lund et al. 2018;

Stahle et al. 2011). Droughts of the Colonial and Independent Periods continued to have socio-political and demographic impacts, as during El Año de Hambre, and the Mexican Revolution (Stahle et al. 2016).

Our evidence and placement of these drought periods derives primarily from paleolimnological research throughout the Maya area (Battistel et al. 2018; see Brenner et al. 2002; Curtis et al. 1996; Krause et al. 2019), often focusing on a comparison of data from sediment cores collected at distant sites. Diatoms present in these cores are particularly exceptional indicators of water quality, and together with analysis of stable isotopes, microfossils, mineralogy, phytoliths, pollen, and other traces present in underwater sediment cores, we can focus on the changing water quality through successive epochs of the site histories of Cobá, Yaxuná, and other sites of the Yaxuná-Cobá corridor. Whitmore and his colleagues (1996) performed an analysis of cores from lakes Cobá, Sayaucil, and San José Chulchaca. These and most other sediment cores in the area were collected from closed basin lakes, as their sediment formation is even over long periods of time. However, *ts'ono'ot* connected to the aquifer are less susceptible to drought, highlighting the importance of looking at varied water bodies and the occupation and activity around them as indicators of changing water management strategies in the face of climate change.

Rainfall variation - whether seasonal, long-term droughts, or heightened hurricanes - is not the only dynamic modulator of the aquifer of the Yucatán Peninsula. Sea-level rise is another key catalyst, which impacts the whole of the hydrological system but more immediately disturbs the morphometry of water bodies and terrain along the coastlines. In some circumstances, sea-level rise may have proved advantageous to certain human activities at coastal sites. The Maya of the maritime trading site of Muyil, for example, were only able to construct canals and navigate the lagoons after they were made deeper from sea-level rise around 312AD creating the wetlands now known as the Sian Ka'an Biosphere (Steele et al. 2023). While the formation of such wetlands and intercoastal waterways may have been a boon to coastal trade in large canoes, other coastal sites may have been abandoned due to the rising salt water, whether from lack of fresh water sources, or simply that they had built to close to shore and had to retreat further inland as the sea swallowed their former abodes.

Further inland, the rising seas coupled with drought may have been a tricky double blow to some water bodies from a human perspective, as certain lakes may have appeared to remain relatively stable during drought, only to be bolstered by increasingly saline water that may have proven detrimental to human occupation. Lake Pac Chen, near Punta Laguna and not far north of Cobá, was one such water body that had a tentative connection to the aquifer (was neither fully closed basin nor fully open to the aquifer, similar to Lake Cobá), and appears to have experienced no lake drawdown through the Terminal Classic droughts, but only due to the intrusion of marine water superseding the now reduced freshwater (Krywy-Janzen et al. 2019). If the nearby inhabitants were growing crops near this lake, especially fruit trees or other trees with deeper roots, they may have found their yields reduced as the saltwater rose without enough replenishing rains to deepen the freshwater lens, while some trees might have died completely.

Archaeological material evidence also supports the general climate trends of various epochs at some sites. Gruta de Chac, for example, which today holds water some 60m below its entrance, contains a higher representation of Early Classic ceramic sherds than Late Classic (Andrews 1965), signifying that the water level may have been somewhat lower in the wake of the drying of the earlier centuries of the Classic period, necessitating a further journey into the cave for water than in the Late Classic. Later, during the droughts of the Terminal Classic, some watering holes would have dried up completely while some cenotes and caves would see their water levels drastically lower than in the preceding centuries of the Late Classic. In some cases, Terminal Classic vessels were carefully placed upon ledges in caves that are now over a dozen meters underwater, like that in the El Pit *cenote* (personal observation), demonstrating lower water levels at that time. In many instances, the placement of such vessels was part of an early version of the *ch'a cháak* rituals of rain supplication.

More recently, geoarchaeology studies (e.g., Wahl et al. 2013; Wollwage et al. 2012) have applied advanced techniques to lacustrine sediment cores to better hone our understanding and chronology of environmental change throughout the Maya area, along with the degree that change has been influenced by human activity. Speleothem records of precipitation and climate change in the Northern Yucatán and elsewhere in Mesoamerica also corroborate and add to this chronology (Lachniet et al. 2017; Medina-Elizalde, Burns, et al. 2016). While increasingly precise and advanced environmental reconstructions have given recent research of this kind more validity, such studies are often at a loss to explain the rise in prominence of some sites while others fall into decline during droughts in the same regions. Beyond deemphasizing the role of cultures and states in directing their own destinies, overarching environmental models often fail to contextualize the nuances of regional and micro-environmental differences and changes (Iannone, Prufer, et al. 2014).

The coring of Laguna Chichankanab by Hodell and colleagues (1995, 2001) was a great boon to better understanding the climate history of the Northern Yucatán and helped to inspire a host of similar subsequent research in the region (e.g., Beach et al. 2015; Gill et al. 2007; Masson 2012; Vela-Pelaez et al. 2018). One of the more enthralling aspects of their research matches intensifications in solar flare activity to major drought cycles roughly every 200 years, and further matches those cycles to major shifts and turmoil in Maya history, including the Terminal Classic decline and the Little Ice Age that preceded Spanish conquest. This is extraordinarily fascinating in light of Maya cosmology, as works like the Chilam Balam reveal their inclination to prophecy and prediction of all manner of future events and disasters, including drought. It is intriguing to wonder if such solar and drought maxima may reflect the cycles of time expressed through Maya astrology and calendric divination (Van Stone 2011: 15-16), which predicts periods of drought during two *k'atuns* especially, 3 Ahau and 10 Ahau, one for each *baktun* half, a period of just under 200 years.

However, Carleton and colleagues (2014) cast doubt on the methodology, interpretations, and conclusions of Hodell and colleagues (2001), manifesting skepticism to a generation of research, only to themselves offer up an environmentally focused explanation of cultural change (Carleton et al. 2017). The two main differences are that they denounce the predictable periodicity of droughts, and they attribute cultural changes to increases in temperature rather than lack of rainfall. Indeed, precipitation cycles have little to do with solar flares and far more to do with local weather patterns stemming from things like temperature extremes and salinity of the Caribbean Sea (Wu et al. 2017). Nevertheless, their conclusions still seem to corroborate some of the earlier work of which they are skeptical, as solar flares would indeed do more to increase heat and evaporate water than it would to prevent rainfall, and their timeframes still match.

Droughts are not just about lack of rainfall, but also available surface or ground water. In the karst landscape of the Yucatán, where rainwater already quickly percolates through much of the limestone into the aquifer lens below, an increase in heat and evaporation for a prolonged period would be just as devastating as a reduction of rainfall, if not more so. It also shifts the focus more squarely on an agricultural dilemma rather than one of potable water for direct consumption. The cultural engineering of *chultun*, and/or the natural water resource of *cenotes*, each would have been able to supply potable water to the local populace through droughts, and both are resistant to evaporation, but it would not have been logistically feasible to use such water sources to irrigate crops. Therefore, the biggest impact of these droughts on the local human populations was most likely one of food scarcity.

This is an important distinction, as a dearth of potable water would clearly spell a quite sudden and near full abandonment of the site or region in peril, while crop failures would likely result in a more gradual decline. Stores of food from previous seasons supplemented by hunting and gathering could sustain a population for a time, as long as there was still a potable water source. Famine foods and/or drought-resistant plants other than the familiar maize, beans, and squash might also be exploited during such crop failures (Dine et al. 2019; Fedick and Santiago 2022; Puleston 1971). Today the ruins of Classic Maya cities are oft frequented by monkeys attracted by fruit trees including the ramon tree, which not only produces tasty (to some) fruit but the nut of which can be eaten, ground into flour, or stored in *chultun* (of the dry variety) for long spans of time with much greater preservation success than the three sisters (Puleston 1971). Other Maya cultivars and wild plants are resistant to even extreme droughts, such as manioc and heart of palm (Fedick and Santiago 2022), but it is unclear what population sizes or densities could be sustained through such plants. Even if, for example, manioc or malanga could theoretically sustain a large population if it were a primary crop, a large and/or population dense city with an agricultural strategy aimed towards one group of crops (like corns, beans, and squash) would be difficult to reengineer towards a completely different type of crop, especially a root crop that might be exceedingly difficult to grow in karst terrain with sparse soil.

Furthermore, simply preventing starvation or malnutrition of the general public is not the only aim of agricultural practices, especially for a powerful Maya polity. Certain fields or a general share of crop yields may have been intended for export and thus played a part in the economic power of Cobá and other Maya kingdoms. In such a scenario, drought would at least erode the economic and political might of the elite if it did not cause out and out calamity and administrative turmoil as the prospect of crop failures pushed many to migrate, leaving the site weak and open to takeover by other polities.

Alternatively, such turmoil could end in the commoners revolting against the elite rulers of a kingdom, city, or *kuchkabal*. In other words, the Maya of many cities at the end of the Classic Period abandoned their palaces, temples, and the "royal theocratic political system that they housed. The Maya did not abandon the forest; without the burden of the elite-based infrastructure, they were sustained by their forest gardens" (Ford and Nigh 2014:106).

Despite debates over the mechanisms and timing of droughts and other long-term climate changes, it appears that more and more scholars concur that major droughts were at least one of the factors that resulted in major upheaval and demographic decline at many Maya urban centers. Indeed, the mounting evidence pointing to such is difficult to ignore at this point. What remains to be untangled are the histories of individual sites in response to these major droughts, and how some were able to overcome them and survive or thrive while others fell.

5.5 Culture History is Environmental History

This chapter has detailed culture histories of the Yaxuná-Cobá corridor, and environmental histories of that region. It is important to note that these are not separate distinct histories connected only by shared space, but intrinsically intertwined stories that influence one another and in many respects are one and the same. Though some mechanisms of climate change like solar flare cycles are beyond the realm of human influence, many of the anthropogenic alterations and interactions with the environment on the ground have an enormous impact on ecological resilience, and such actions can be crucial to the ability to adapt to climate change, or not.

At Tikal, for example, agricultural engineering and water management systems pushed the land to its yield capacity and left the populace of Tikal vulnerable to a long drought that likely contributed to its decline in the ninth century AD (Lentz et al. 2014). This ecological destabilization befell despite advanced and sophisticated engineering at that site, as discussed earlier in this chapter. However, not all alterations of the past environment were ecologically detrimental; the built environment at Copan included water management practices and environmental conservation that encouraged the regrowth of forest, agricultural field, and garden alike (McNeil et al. 2010).

Figure 5.4 Images of an ancient *ch'e'en* at Cobá from within the well (left) and above (right).

Such variability in water management practices through time and space throughout the Maya world reflects cultural, political, and historical particularities, but also adaptive strategies for a variety of environments and climate cycles through time.

Such strategies are perhaps more difficult to decipher at sites along the Yaxuná-Cobá corridor, with no great reservoirs or canals as in the south, or numerous *chultun* as in the Puuc. However, smaller localized reservoirs and some *chultun* and *ch'e'en* (Figure 5.4) do exist at Cobá and elsewhere in this region, which supplemented the extant *cenotes* and lakes (Folan et al. 1983). All of these water features will be a prime focus of my data analysis, to be explored further in the following chapters.

Chapter 6 Methodology

6.1 Introduction

In order to meticulously examine the differences concerning drought resilience between and within regions and sites in the Yaxuná-Cobá corridor, this research compares evidence for occupation near water features between sites and groups within sites along this corridor over time. Such water bodies were identified and delineated in lidar data, and those on which this project focuses most were ground-verified, surveyed, and off-mound test pits were conducted at nearby structures to provide ceramics for chronological control, amongst other artifacts that might speak to activities near the water features. These data help refine and establish regional, site-specific, and variable intrasite responses and resilience to drought of the Maya of the northern Yucatán.

First, I determined the concentration of structure area and volume (rather than simply by number of structures) in the lidar data, a la Stanton and colleagues (2020) at Cobá, applied it throughout the Sakbej 1 corridor, and compared it to the concentration of the surface area of water sources in the same areas, by generating "heatmaps" (data visualizations that portray densities of values as colors, with reds commonly used to indicate the densest or "hottest" areas) within the lidar datasets. Of course, volume of these water bodies is impossible to tell from the lidar alone, but surface area still gives a sense of available water sources and is supplemented with pedestrian survey of water bodies where possible, as well as bathymetry data or estimates where available. Ease of access to water sources is important; therefore, the distance from surface water to ground level was also considered in these calculations. Water samples were taken when logistically possible, as water quality may also shape activity and use of a water source. In addition to structure area and volume, the form of architecture near water bodies was noted to better understand not only the population estimates over time, but also possible specialized activities, inequality of water access, and changes of usage and access during times of drought or other crises.

Through working with the data and spending time in the field, I realized that linear features were paramount to this research and may strongly impact water management, and thus classified them in the lidar as either *sakbej*, *sakbej*-walls, *chichbe*, *t'úubulbej*, or *albarradas*. These categories allowed further examination through heatmap comparisons, statistical analyses, and proximity to water sources, houselots, monumental architecture, and other features. Finally, previously collected occupation data was reviewed from past excavations (when available) as well as my own such data from test pits at some of these sites.

Two other methods or training inspired my research but do not contain sections below as they were not part of the actual data collection. In the Yucatán, I completed my full cave diving training, and scuba dove many *cenotes* along the east coast of Quintana Roo, on the island of Cozumel, and inland as far west as the greater Mérida area. While not diving these in an archaeological capacity, and always refraining from touching or disturbing any artifacts, these dives still heavily guided my understanding of the underground water systems of the peninsula, their changes over time, and the Maya connection to them. Secondly, lessons in the Yukatek Maya language were enormously beneficial to my understanding of Maya culture, cosmology, thinking, and perspectives toward water features, the landscape, and a great many other things.

6.2 Lidar Data Collection

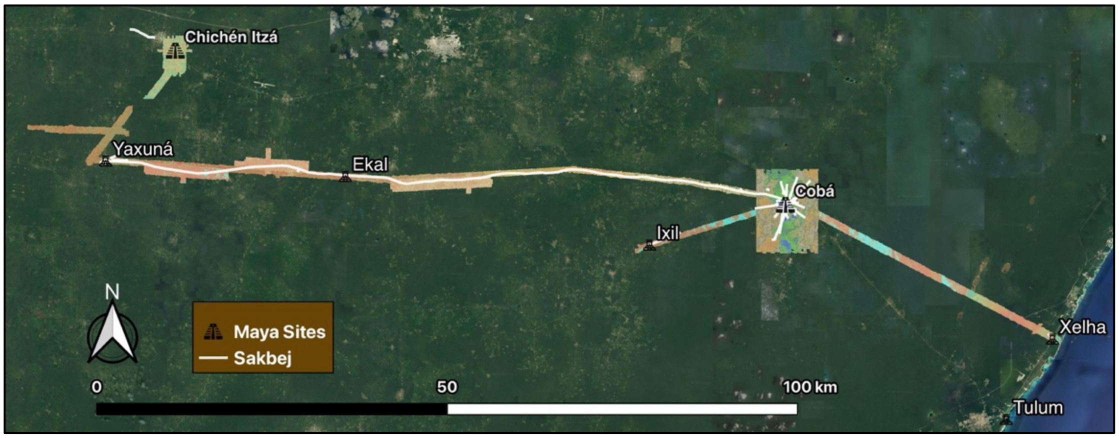

Figure 6.1 Map showing locations of lidar data.

The framework for the methodology for my research begins first with the lidar data collection, which took place in 2014 and 2017 at Yaxuná, Cobá, and other sites (Figure 6.1). In 2014 the National Center for Airborne Laser Mapping (NCALM) recorded 66.8 km^2 of point cloud lidar data for PIPCY and the Chichén Itzá INAH project. This zone covered the whole of Yaxuná, a central block that comprised most of Chichén Itzá, a kilometer-wide transect connecting those two blocks, and another kilometer-wide transect extending east from Yaxuná along Sakbej 1 for four kilometers (Magnoni, Stanton, et al. 2016). An Optech Gemini allowed as many as four returns per laser shot at 500 m altitude. The pulse repetition frequency (PRF) of the sensor was set to 125 kHz, with a beam divergence of 0.8 milliradians. The scanner was operated at ± 14° and 45 Hz. Together these parameters yield a shot density of 15 shots/m^2, resulting in an average 18 percent surface illumination. Heavy rains in 2014 created a high degree of vegetative noise (Magnoni, Stanton, et al. 2016), mitigated by recovering some of the more problematic areas on the later 2017 run. Clearly, the variation in seasonal and annual rainfall influences virtually every aspect of life in the Yucatán, and our data collection efforts are no exception.

In 2017 we extended lidar coverage in several areas, including a one kilometer wide transect along the most likely path of Sakbej 1 as well as an approximately 104 km^2 area around Cobá. The lidar data of Cobá, Yaxuná, and Sakbej 1 are the primary foci of this dissertation research and comprise my sample size (~210 km^2 total) in terms of lidar analysis, but other recorded areas of note from 2017 include a kilometer-wide transect between Cobá and Ixil, a few small block surveys at sites close to Yaxuná, and expansion of the lidar survey areas around both Yaxuná and Chichén Itzá.

In preparing the flightpath for Sakbej 1, we used a shapefile from Witschey and Brown, choosing the northernmost path to guide the flight. Vegetative noise as experienced in the 2014 data was significantly reduced in the 2017 data, due to a much milder rainy season that year, wildfires which removed much of the denser low-lying vegetation, and the use of updated gear. This time, a Teledyne-Optech Titan MW was deployed, a multispectral lidar that simultaneously emits laser pulses at 1550 nm, 1064 nm, and 532 nm wavelengths with a PRF range of 50-300 kHz (Fernandez-Diaz et al. 2016). Smaller features like platform edges and linear features are far clearer in the 2017 data, which was crucial, especially while sorting structures and linear features, discussed below.

6.3 Lidar Data Processing

Upon collecting this raw lidar data, several stratagems can be utilized to render the spatial point cloud data into different forms of useful datasets. For archaeological purposes, the most common useful datasets are digital elevation models, or DEMs. Such DEMs are rendered as shapefiles (.shp, along with multiple other file types which store various attributes), for use with ArcGIS, QGIS, and other geographic information systems software. While these shapefiles are not rendered in three dimensions in such software, using a combination of a colored DEM and a DEM hillshade model, we can approximate the look of a topographic relief map. Truly three-dimensional models of DEMs are achievable, even to print as 3D models, but such renderings are often better for small scale analyses than for looking at large sites and regions.

In combination with the hillshade DEMs, colorized DEMs and other GIS tools such as slope, simplified local relief models (SLRMs), or aspect DEMs can make certain features more visible or "pop out." The colorization especially facilitates the identification of water features, as well as areas of even shallow sloping depressions like *rejolladas*. Testing out various visualization tools like those found in the Relief Visualization Toolbox (RTV) - such as sky view factor (SVF) - is another practical way to see certain details more clearly. Combining them or double-checking work with varied visualizations is often very helpful. For example, an open positive model with high contrast coloring and a 50% transparency overlaid on a hillshade model can help thin linear features appear sharper and more defined that may be hard to spot with other visualizations or combinations thereof. An increasingly popular imaging scheme known as Simple Red Relief (SRR) developed by Luke Auld-Thomas (Canuto et al. 2018) is exceedingly successful at highlighting many features in relatively flat terrain, but I found that many of the small thin linear features were better identified through the use of Singleband Pseudocolor over Hillshade, and adjusting the color bands with many slight changes at the appropriate ranges.

Additional raster extrapolations can also be beneficial. Slope tools can help us get a sense of what land might be eligible for *milpa* farming (Bernsten and Herdt 1977; Ford et al. 2009) or other uses, thus it proved helpful to create various slope models on the Cobá data to visualize potential *milpa* areas, using thresholds of 7% and 15%, and disqualifying areas occupied by structures, *sakbej*, modern buildings and disturbances, plazas/groups, and infield buffers around groups considered to be home gardens and orchards around houselots (Folan 1978; Lentz et al. 2015; Tozzer 1941:62–64). I also ran many algorithms to approximate rainwater runoff, but this was a challenge as the area in which we work is so flat that most models resulted in either too little contrast in their data or far too much noise. However, after lowering the resolution of the DEM to 3m and running the SAGA Parallelizable Flow Accumulation tool, results were obtained modeling possible water flows over the landscape. Using that model, values were transferred into points along linear features (discussed below) in order to gauge their impact on channeling rainwater.

After rendering these DEM visualizations, the next task was to work with the most appropriate model for each type of feature and create shapefiles to map these features. Additionally, transparent overlay maps were created from the images published by Folan and colleagues (1983) and georeferenced by matching up key features such as the corners of structures or the intersection of two linear features. Unfortunately, many features on these maps are poorly placed and/or oriented. However, after georeferencing as best as possible, even though the overlay may not match up neatly, I could locate small features recorded by that older project and label them on the lidar, including wells, catchment basins, and small aguadas. Otherwise, such features might have been missed, but instead identifying them in these circumstances also trained my eye for similar features in contexts outside of the area mapped by Folan and crew. The literal backgrounds of modified DEM visualizations and previous mapping then set the stage for digitizing features into shapefiles, discussed below.

6.4 Lidar Data Interpretation & Analysis

In reviewing and analyzing the lidar DEM maps, we seek to label and categorize several key elements: structures/buildings (their base areas), water bodies, *sakbej*, and other linear features like *albarradas*. Initial viewing of the lidar data in this region can be perplexing in some areas. Especially in the region around and just east of Yaxuná, many geologic features of the karst topography might deceive the untrained eye into labeling a hummock (*búuk'tun*) as an ancient Maya structure (*múul*), or a geomorphic long concentrated rise in the bedrock as a large *albarrada* or perhaps even a defensive wall. To complicate matters further, some hummocks with relatively flat plateaued tops make excellent locales for Maya both past and present to build a home or other structure. However, after spending many hours with the lidar maps, changing settings, and viewing different angles, the distinction between constructed and geological landscape becomes much clearer. More importantly, time spent on the ground verifying and comparing the lidar to the reality is very impactful on differentiating various kinds of features, and their veracity as such. Members of the PIPCY/PSYC project contributed toward labeling features superimposed upon the lidar DEM maps by creating additional shapefiles for structure bases, *sakbej*, linear features, and water bodies. For the more specific areas analyzed for this research, I either ground-verified the lidar myself or double-checked the work of others to reach a consensus on classification and labeling.

6.5 Structures Classification

There are many different ways to classify and quantify the general category of structures. Buildings in the ancient Maya world had an enormous range of scale, form, function, architectural craftsmanship, building materials, and many other qualities. For my research, one of the most immediately important considerations is to determine the density of any structures near water features, but even that has options. One could simply identify unique structural units and determine density by number of structures within a given area, but this ignores the variations in size, wherein one may have housed many more people, provided for more food storage, or accommodated for larger public gatherings. Thus, it was more helpful to compare heatmaps of structure density by the volume of structures, as crafted by Stanton and colleagues (2020).

Additionally, it is critical to consider the nature of use of structures, or function. Some massive structures may indicate extreme importance and considerable labor, but housed few to no people, as in the case of large temples and public buildings. Contrariwise, many miniscule structures might have only been storage sheds, temporary shelters while working the fields, lime kilns, or other non-residential spaces. Clearly, such structures should not be tallied or incorporated into volumetrics when tabulating population size, but they still serve important functions. Fortunately, Stanton and his colleagues (2024; see also Hutson et al. 2023) have classified residential structures at Cobá into the following categories, with a shapefile for each: base area (platform or similar raised area on which to build), foundation brace off base area, foundation brace on base area, structure on base area, and structure off base area. Supplementary types and notes were recorded within some of these shapefiles, such as annular shaped structures. Stanton and colleagues double-checked each other's work and modified shapes when necessary. I also made slight adjustments and revisions, especially in those areas I ground-verified myself or otherwise worked with the data on a closer level.

Based on the location and position of the above structures, Stanton and colleagues (2024) also created a point shapefile estimating the centers of houselots, or groups. In some cases, groups have clear boundary markers in the form of albarradas or other linear features (discussed below), while at other times they are more difficult to define in area and dividing lines. Using this group shapefile, I calculated Average Nearest Neighbor (ANN) and also utilized this data to approximate infield buffer areas and other analyses relating to land use.

In addition to the above structures, I also digitized *ch'ich'* mounds, low mounds of limestone cobbles and gravel that were likely utilized to support young trees (Kepecs and Boucher 1996), but in some cases large mounds of *ch'ich'* were platforms for fieldhouses (Kunen and Hughbanks 2003) or small houses (Pyburn et al. 1998). *Ch'ich'* mounds are more difficult to discern than larger and more formal structures, but they present in the lidar as small circular or oblong mounds, often in clusters near formal structures and/or linear features.

6.6 Water Features Classification

Identifying water features in the lidar DEM was fairly straightforward, although some very small and/or shallow features are harder to detect. Water bodies were separated into two main shapefiles: permanent water bodies with water all year, and seasonal *aguadas* or catchment basins that would fill up in the rainy season but gradually dissipate and dry up in the dry season unless manually filled. At times they could be difficult to differentiate due to vegetative noise from plants like water lilies and bulrushes, but most permanent water bodies had large flat mostly solid surfaces, while most seasonal water bodies had much higher levels of vegetative noise, and in many cases the difference was verified by surface survey and/or previous research. Colorizing the DEMs so that all elevations within a given bottom range (this varied by lidar data block) appeared as shades of blue was the easiest way to spot water features. To spot smaller water features, a lidar raster layer was created that kept only the lower elevation range and removed the rest, in order to pick out small features without background noise.

Within the permanent water bodies shapefile, types were noted to delineate between closed-basin systems like lakes and swamps, and bodies which connect to the aquifer like *cenotes*. I noted those that were ground-verified or otherwise can be certain of such discrepancies through either known mapped bodies or clear indications in the lidar imaging. This distinction can sometimes become blurred in the northern Yucatán (as discussed in Chapter 4). For example, one or more of the large lakes in central Cobá almost certainly contain small openings in their basins that connect to the aquifer, evidenced by species of ocean fish (e.g., *Megalops atlanticus*) appearing in them after heavy rains. These openings may be covered by sediment sometimes, but others are partially cleared to allow for the flow of water between the aquifer and the lake. Such a phenomenon would account for the fairly equal water levels above sea level between the lakes and *cenotes* in the area.

6.7 Linear Features Classification

Fletcher (1978; see also Folan et al. 1983) divided linear features at Cobá into three main categories: "single-faced, double-faced, and sacbe-like" (Fletcher 1978:iii). Additional subcategories they based more on presumed function and associated architecture, such as houselot walls and walls around raised gardens, but for my purposes here such distinctions are unnecessary and would only cause confusion and muddle the methodology. Though I mention some of these details and differences on a case-by-case basis (in Chapter 8), the four categories discussed below are the simplest and clearest way for me to classify these linear features, especially in regard to lidar and GIS data systems. However, it is still very relevant to describe some of the likely functions of these linear features, which I detail in the succeeding chapter. For now, I will focus more on the form to differentiate categorization when selecting shapefile units when working with the lidar data.

There are many different types of linear features, a broad and basic category. Many low-lying walls in the Yucatán are known as *albarradas*, but in some cases when they form an enclosed space like a cemetery, they may be called *bardas* - *koot* in Maya - a term also used for higher walls/fences of very simple construction used in colonial, historic, and even recent times to hold cattle. Other linear features may be simple earthen barriers, made from packed earth - mostly *chak lu'um*, as its clay content helped to prevent erosion in the short term. However, only some categories of linear features both relate to this research and are distinct in the archaeological record. These four categories are *sakbej*, *chichbe*, *albarradas*, and *t'úubulbej*, discussed below.

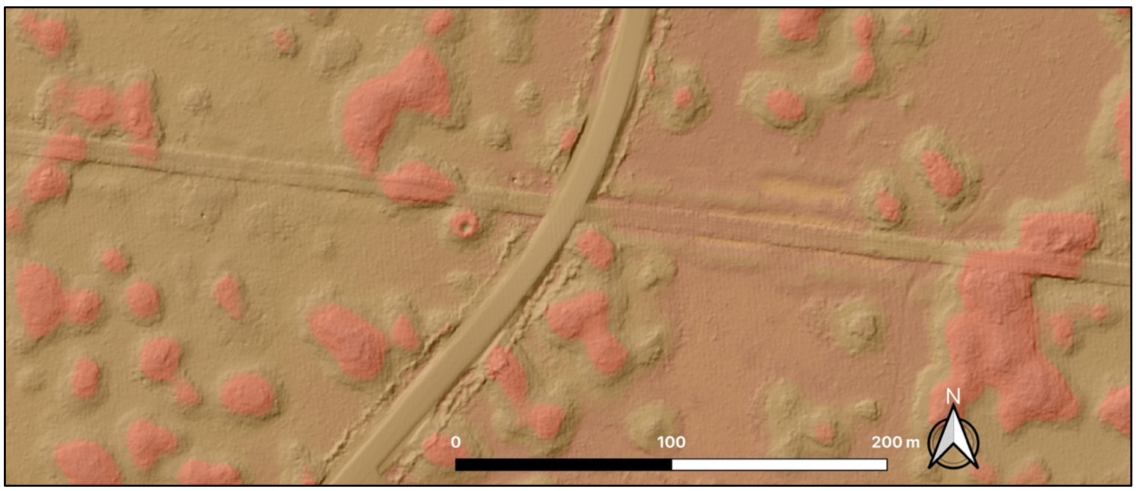

Figure 6.2 Lidar map demonstrating a *sakbej* and a contemporary road. Sakbej 1 runs east to west while the more recently built asphalt road cuts through it curving vaguely north to south.

Sakbej were constructed with two parallel retaining walls of roughly faced stones filled in with smaller rubble (*ch'ich'*) and topped with *saskab* and/or other fine material tamped down to create a flat smooth surface. They vary in size but are normally between 3-10m in width, with some very wide exceptions usually near large elite complexes, and occasional small narrow *sakbej* only about 1m wide. Most in and around Cobá, including Sakbej 1, are typically about 10m wide. Formal and relatively uniform in construction (see Chapter 9 for considerations of variations in uniformity of Sakbej 1), they were assembled in sections from one high point to another, as straight and with as gentle a slope as possible. *Sakbej* present in the lidar as similar to contemporary roads, flat long uniform stretches with lower troughs on either side (Figure 6.2), and indeed their lidar signature may be mistaken for asphalt roads to the untrained eye.

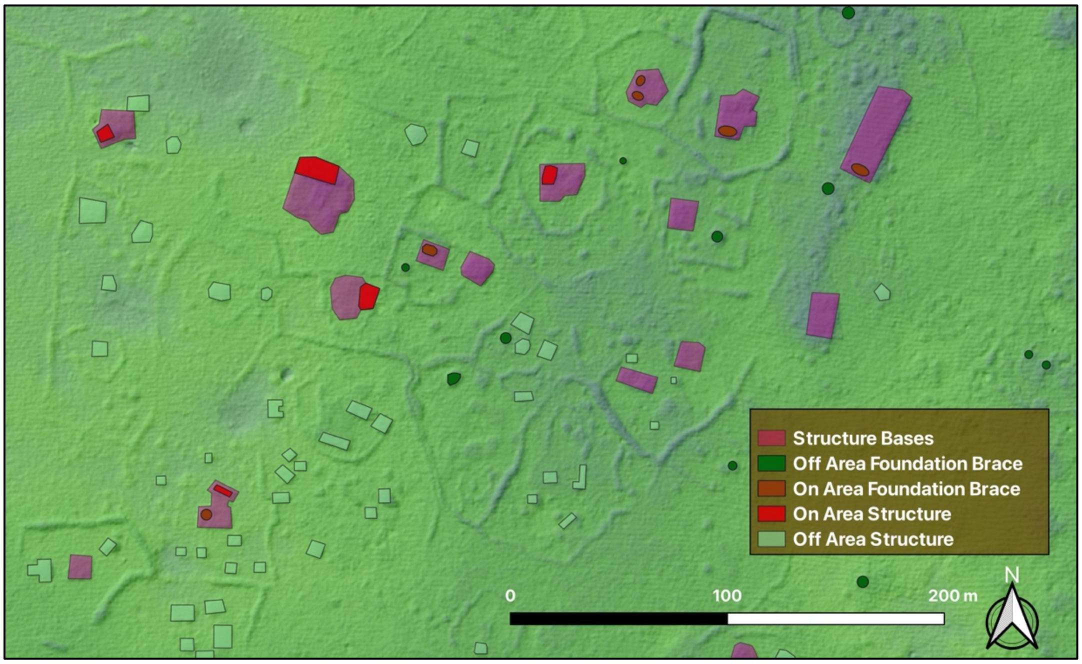

Figure 6.3 Lidar map demonstrating *chichbe* surrounding and connecting houselots.

Chichbe is a term coined (but also a word in Yukatek, see Preface I) by Magnoni and colleagues (2012) from their work at Chunchucmil. *Chichbe* are very similar in rough form and construction to *sakbej*, but primarily differ in a lack of retaining walls. Because of this lack of retaining walls, *chichbe* tend toward an elongated mound shape rather than a flat road. They are also rarely straight, but rather curve and wind along, and are generally not as wide nor as finely constructed as *sakbej*, seemingly less formal and more localized. Most chichbe at Cobá are roughly 3m wide, though some are as narrow as 1m across, and are typically about 1m tall. *Chichbe* present in the lidar as winding raised lines in the terrain (Figure 6.3), somewhat rounded without the crisp flat plateaus of *sakbej*, and usually much higher/taller than the surrounding terrain in comparison to *albarradas* or *t'úubulbej*, discussed below. In some areas, large narrow raised lengths of bedrock (as a consequence of geological forces) could be mistaken for *chichbe* in the lidar, but these are almost always much larger and more irregular than any human construction, so again a trained observer should easily avoid this discrepancy for labeling.

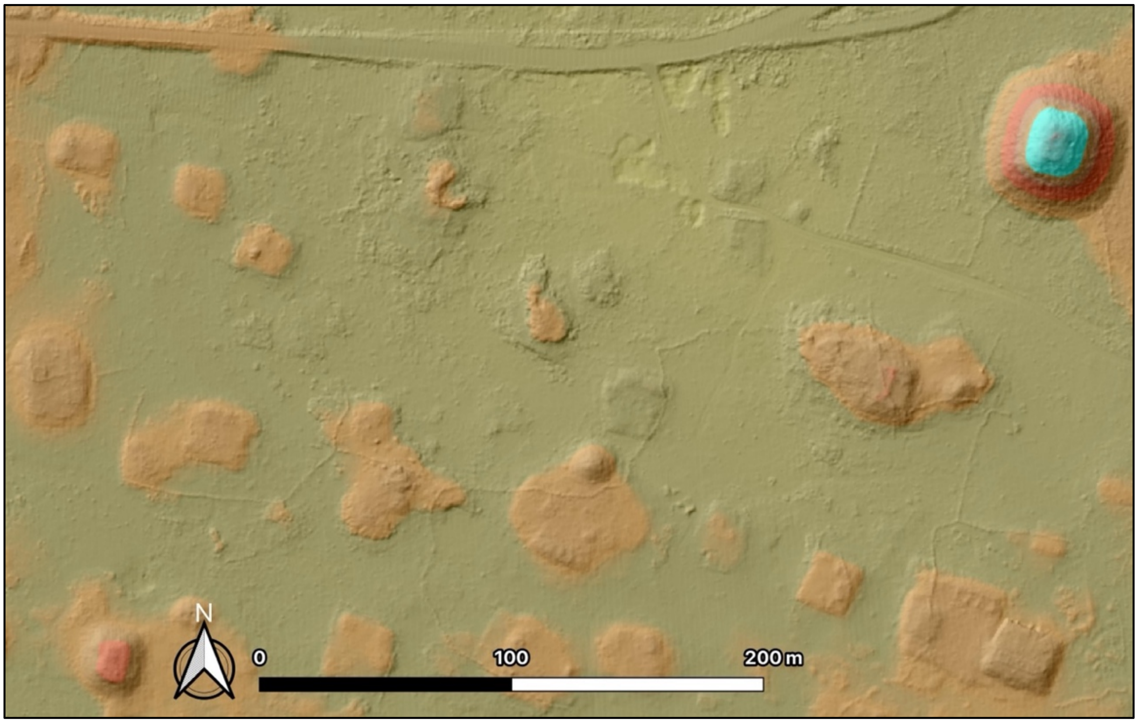

Figure 6.4 Lidar map demonstrating *albarradas* (small thin lines) amongst ancient structures. Note that in this case they are all contemporary boundary walls for milpas set down by the local Yaxuneros.

Albarradas are simple low-lying "walls" consisting mostly of medium sized stones about 20-50cm long and 10-40cm wide and deep, placed tightly together but without mortar. They often run straight, but many *albarrada* lines can also be curved or winding. Although some contemporary albarradas are neatly stacked with several courses and thus resemble a proper low wall, others are cruder piled lines of stone, thus it is difficult to tell if ancient *albarradas* are collapsed or closer to their original form.

Albarradas present in the lidar as narrow lines with minor yet distinct relief above the surrounding land, and with little to no smoothness/flatness (Figure 6.4).

T'úubulbej is a term I have adopted here after the Yukatek Maya term *tun t'úubul bej*, meaning "submerged/waterlogged road of stones," (see Preface I) to describe a distinct linear feature, as there is little discussion of them in previous literature. The Isla Cerritos project researchers (Andrews et al. 1984:17, 1988) mention stone walkways to get around during the rainy season, or across tidal flats, but these consisted of "large flat slabs placed horizontally, at intervals of a few inches, on the swamp bottom" and thus distinct from the feature discussed below. Similar features at Chunchucmil and other sites are labeled *andadores* by previous researchers (Ardren et al. 2017; Benavides Castillo 1981b:210; Glover et al. 2022; Hixson 2011; Hutson and Magnoni 2017; Leonard 2013; Magnoni et al. 2012; Vargas Pacheco et al. 1985), but in this work I prefer the specific word *t'úubulbej* to delineate from other varieties of paths or walkways associated with the term *andadores*, as there has been some confusion in the literature on whether *andadores* are simply *chichbe*, a type of *chichbe*, *callejuelas* (pathways formed between parallel running *albarradas*), or something else altogether. This is understandable considering the vague and broad possible meanings of the Spanish word *andador*, which can mean anything from sidewalk to boardwalk in the context of walkways, but more commonly glosses in modern Spanish as the kind of walker that is an ambulatory aid for the elderly or disabled, or a device to aid in infants learning to walk. The confusion stems in part with a conflation of form and function, as noted by Magnoni and her colleagues (2012:316). A report from the site of Emal describes many stone *alineamientos* (Johnson

2014), some of which vaguely resemble *t'úubulbej*, but, like Isla Cerritos and Paso del Cerro (a mainland site associated with Isla Cerritos, see Andrews and Negrón 1986), Emal's location along the coast and use as a saltworks place it in an environmental niche distinct from that of Cobá and other inland sites, and so these features may have been equally distinct from those at Cobá, perhaps bases for docks.

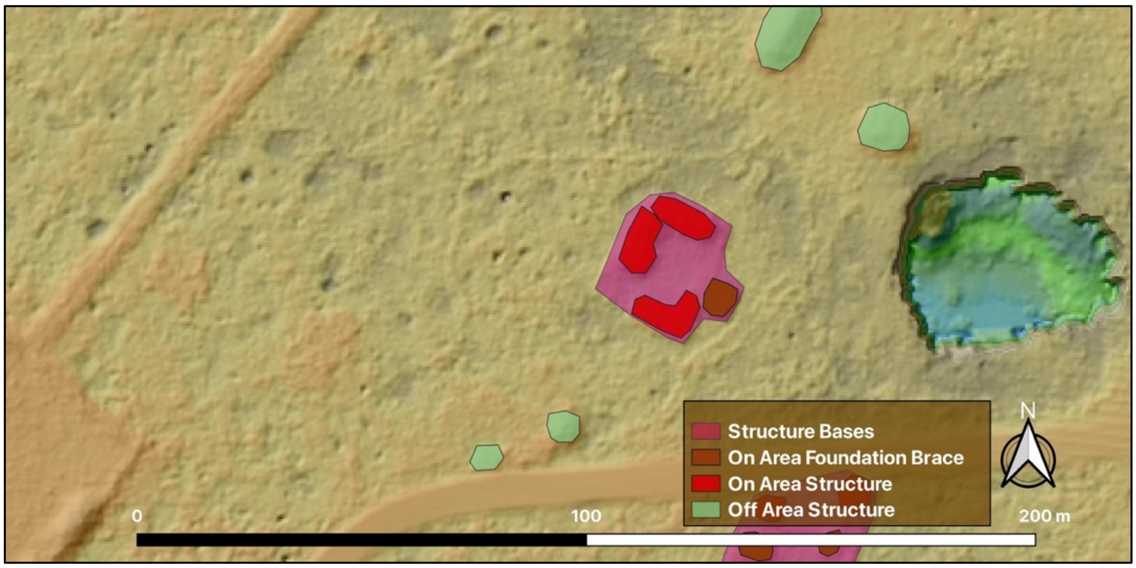

Figure 6.5 Lidar map demonstrating *t'úubulbej* surrounding a group. Note how the lines appear bumpy or dotted, and the run of parallel double lines of t'úubulbej to the southeast of this group near Kitamna.

T'úubulbej are lines of rough-hewn boulders ranging roughly 1-3m^3 on average, with significant gaps between each boulder creating a steppingstone path. They may be curvy or straight. *T'úubulbej* present in the lidar as dotted or "bumpy" lines (Figure 6.5), and often cross over other linear features, and run up to - or even into or over - ancient platforms and structures. They often are found in lower lying areas, including running into water bodies and sometimes disappearing into them, which makes them of particular interest to my research.

In digitizing and drawing these linear features over the lidar DEMs, inevitably some errors will occur. Though some lines are clearly one type of linear feature or another, many are small and difficult to make out even with the variety of tools available with GIS software. I am certain that some lines drawn and classified as *t'úubulbej* will turn out to be *albarradas* or *chichbe*, for instance, or the other way around. There is also the consideration that these are heuristic categories and the distinction between one to another is sometimes blurred. For example, Magnoni and colleagues (2012:316–317 Figure 4) include an image from Chunchucmil of an *albarrada* made by a course of large boulders, on the cusp between *albarrada* and *t'úubulbej*, to my eye and mind. Other lines in the lidar may actually be geological features, vegetative noise or other noise in the lidar data, or the edges of modern paths. Still, I am confident that, with my experience in the field in conjunction with ground-verifying and the many hours spent with this data, the vast majority of the drawn features correspond to their proper heuristic type description. Future work in the field will allow us to determine the percentage of error, and perhaps to adjust these types for continued research.

6.8 Shapefile Analysis Methods

After creating and obtaining the above shapefiles (multiple structure, water, and linear feature shapefiles) I ran various analyses. Heatmaps are a good starting point to get a better sense of the distribution and density of features and how they correlate to one another. Such heatmaps may be based on numbers of features alone, but for most of these features that might betray the reality of the site. As noted above, Stanton and colleagues

(2020) addressed this issue by calculating the area and volume of structures in addition to merely the structure count and comparing the varying densities of the resulting heatmaps.

Likewise, the lengths of linear features were calculated, while correlating the vertices of each line with the z-value elevations from the lidar DEM raster data. In doing so, I was able to find average lengths and elevations for each type of linear feature, refine those by area, and correlate the spatial distribution of these attributes into heatmaps. Running statistical analyses of the correlations between distance of linear features to water features and weighing length in said statistics was considered, but I quickly realized that the distribution of all linear features would clearly by correlated toward water features because there is often a greater degree of occupation there, and thus the results, even if significant, would not reveal any new information about settlement patterns. Similarly, a simple comparison of elevation averages does not necessarily correlate to one feature or another favoring lower-lying areas that may be more prone to flooding, as pockets of higher elevation may have flooded if they were lower than the surrounding areas, even if well above the water table and sea level. That said, this data was adapted into my summary of data analysis and incorporated into heatmaps to look for patterns.

6.9 Ground-verifying: Pedestrian Survey with Lidar

To ground all of this lidar data collection, processing, analysis, and classification into tangible reality requires on-the-ground pedestrian survey. Traditionally, theodolites or total stations have been the primary tools to survey the structures, features, and other points of interest for archaeologists. The DEM maps from lidar data save us enormous amounts of time in collecting such data, but it still of course requires field methods and some basic equipment and understanding of former methods. In addition, data from total stations can still be useful and combined with lidar into GIS programs to verify feature locations, compare methodological tools, and provide more precision in some cases. Due to the COVID-19 pandemic, I was not able to perform as much ground-verification as initially planned, but I expect to carry out future research of a similar nature that will continue this research at sites along Sakbej 1 and elsewhere.

Some of the most primary tools and considerations of pedestrian survey in the jungles of the Yucatán remain the same, regardless of technological upgrades. Lidar is so spectacular, because it allows us to peer through dense forests, but in real ground survey we must find a way through those forests with machetes, proper boots and clothing, and lots of water in addition to any survey materials we may carry. Another huge boon to navigate these jungles is traditional and local knowledge, one of the many reasons we hire the local *ejiditarios* to aid us in these endeavors, as they know and understand their land better than anyone. In some cases, we may spot *brechas* or other trails in the lidar data and thus be able to plan ahead of the field for access routes, but these trails may change from year to year, and the *ejiditarios* know best the conditions of the season, which areas to avoid, which paths to utilize, and how accessible an area may be.

Navigation to a feature or area of research interest is also aided by GPS, and both lidar and satellite maps. These techniques were adapted from those developed by Nic Barth at UCR, known as the GeoPad Digital Field Mapping System, primarily established for geological research. Using an iPad Mini 2 (running the latest iOS) and the software/app FieldMove, we upload georeferenced images (geotiff files) of the lidar and overlay them on existing public access maps (with either satellite imagery and/or street maps) for general reference and to verify that the lidar is properly georeferenced within the software. Then our location on the map and thus the lidar data can be tracked live in the field, either with the iPad's own GPS system, or by connecting it to a Bad Elf GPS or other external device with a strong GPS signal. Additional helpful tools for this method include a stylus for interacting with the iPad, backup batteries for long days in the field, and sturdy cases to protect from the dirt and grime encountered in fieldwork.

Having reached a destination or area to survey, we may then record structures and features by drawing them onto the lidar maps directly and take photos of points of interest that are georeferenced as well. While FieldMove allows for (indeed one of its primary features) drawing on the map with various colors and styles within the software, initial testing of this feature in the field was met with limited success, more often than not resulting in saved files with distorted lines that had originally been drawn straight. Therefore, we further adapted our survey methods by printing out lidar maps (in parcels, on a 1:40 scale) and drawing structures and features directly on to these paper copies. Upon returning to the lab, we were then able to render these drawings into ArcGIS and QGIS as shapefiles, with no issues (Stanton, Ardren, et al. 2020:5).

6.10 Excavation Methods

For the purposes of this research, excavations were limited largely to test pits, as the principal data needed were ceramic materials diagnostic for dating purposes. Most test pits were dug near water bodies (lakes, *cenotes*, and swampy areas) with ancient structures close by. Some such areas were already known from previous research and survey, while others were selected with the aid of lidar data.

Due to logistical constraints associated with the pandemic, I performed only one test pit at Yaxuná, near Cenote Xauil, but previous data collected by other project members in and around Yaxuná near *cenotes* also informed and contributed to my research (e.g., Stanton et al. 2010). I plan to continue this research, especially at sites along Sakbej 1. At Cobá, my team and I carried out 17 test pit excavations. Most of the test pit locations were selected with lidar as a guide, targeting areas with structures near *cenotes* or other water bodies, many of which tended to be near *sakbej* termini. All of these test pits were "off-mound" excavations, usually placed nearby structures but not on them. Other crews on the PSYC project also excavated test pits (as well as surveyed), which also informed this research, even if those were not focused on areas near water bodies.

Most test pit excavations were 1m x 1m, although in rare cases they were expanded to 2m x 2m excavations to allow us to reach bedrock in at least part of the pit. Vertical control of the excavation was achieved through arbitrary 20cm levels, but new levels were changed early when we encountered sharp changes in soil horizons and/or architectural features, like floors. The removed matrix was screened with 1/4" mesh, and artifacts (mainly ceramic sherds, and some fragments of obsidian, chert, and shell) were removed either from the excavation itself directly or from the screens and bagged and tagged for further analysis in the lab. Photos were taken of each test pit before start of excavation and when changing levels or lots (lots consisting of discrete areas of interest within levels, which were not encountered in these test pits). Any architectural features or other features of interest were measured in plan drawings, and profile drawings of the excavation limits were drawn at the completion of each test pit excavation. Finally, a marker (flagging tape) was placed at the bottom of the excavation to indicate our archaeological presence, and the pit was backfilled with the excavated materials minus any removed artifacts.

6.11 Artifact Analysis Methods

Back at our base camp and field lab, we washed and processed artifacts, including weighing them after they dried, and photographing a sample of ceramic sherds and other artifacts. The foremost artifact which helps with chronology and occupation ranges are ceramics, which are often diagnostic for both regional types and time periods that correlate to ceramic horizons. The bulk of the identification of these ceramic types for this research was conducted by Iliana Ancona Aragón, using the type-variety method (e.g., Robles Castellanos 1990; Smith 1971). Chert, shell, obsidian, and other artifacts are also important artifacts to process and enumerate, for what they may tell us about trade networks, labor practices, and a variety of other social modalities and changes. I also weighed such artifacts per excavation lot, and photographed samples.

6.12 Water Quality Testing

In addition to the analysis of the artifacts themselves, my research on water led me to consider analyzing the water itself. I ordered water testing kits through EarthEcho International (manufactured by LaMotte Company), which measure temperature and test for dissolved oxygen, pH, total alkalinity, total hardness, and calcium hardness. I also obtained more advanced testing kits to test for chlorine dioxide, nitrite, nitrate, sulfate, chloride, copper, iron, free chlorine, water metals, hydrogen sulfide, lead, pesticides, and coliform bacteria. While water quality may change over time (long term and seasonally), and modern pollution certainly influences these readings today, the ancient Maya also contended with fecal pollution and other biohazards, and with a much larger population that exists there today. Also, water from caves or other sources could contain high amounts of calcium that would only be safe to drink for short periods of time (a week or two) before it became unhealthy for the human body. For these reasons, water quality analysis can be helpful despite the ever-changing nature of the water cycle.

6.13 Methodological Tools Conclusion

The combination of lidar data and other GIS tools, pedestrian survey, test pit excavations, artifact analysis, and water testing, forms analytical approaches to addressing my questions regarding water management and resilience to drought and climate change amongst the populations of Cobá, Yaxuná, and other settlements along Sakbej 1 through time, especially through the Terminal Classic. Other techniques such as soil cores and soil chemistry analysis (both within excavations and from sediment collected from the bottom of water bodies) might also aid this research, but time and logistics due to the pandemic did not allow for such efforts for the current study. Fortunately, sediment cores of lakes at Cobá and other areas of the Northern Yucatán have been carried out by others and will also support and inform my research, as well as the previous archaeological studies at these sites and in the region discussed in previous chapters. The succeeding chapter breaks down the results of these methods and analyzes the data collected as they enlighten my research questions.

Chapter 7 Excavation Data Results and Analyses

7.1 Introduction

This chapter breaks down and details the results of the excavation data for this research, namely: the locations and descriptions of each test pit and the artifacts recovered from them. The majority of this data correlates to Cobá, with a single test pit in Yaxuná. This will set the stage for additional analyses of lidar and water quality data in the proceeding chapter, where it will be compared to the excavation data discussed here.

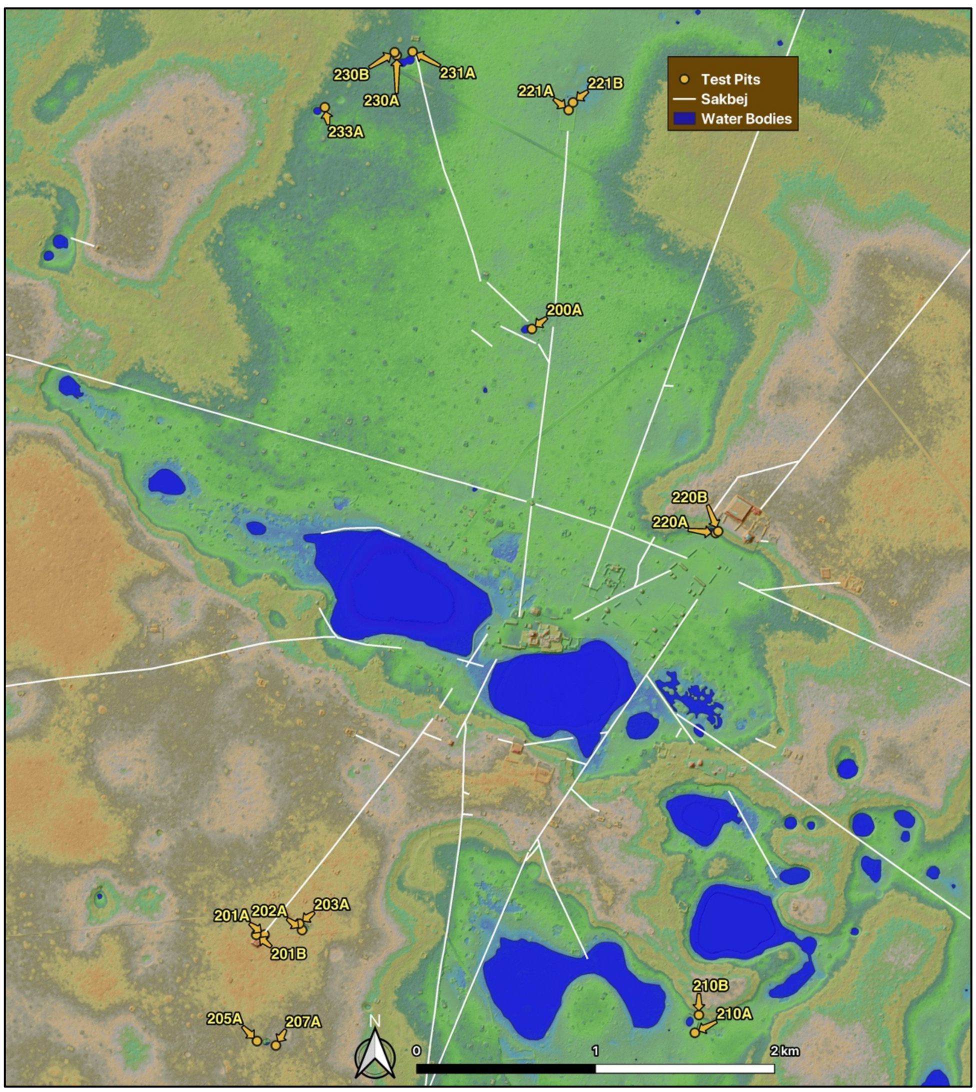

Figure 7.1 Map of Cobá with test pit excavation locations.

7.2 Test Pit Excavations & Corresponding Groups

The following synopses describe the test pit excavations dug at Cobá in 2018 (Figure 7.1) and one test pit from Yaxuná in 2017. The proximity to water features was paramount in the selection of test pit locations in order to investigate questions of water management and variation of usage. Though the excavations themselves were off-mound (i.e., not on or within any buildings) test pits, they were often within or very near major plazas or large household groups, some at causeway termini, and within range of a major water body or water source. These nearby groups were not only ground verified but also often explored in more detail than other areas of ground survey, as more time was spent amongst them. First, I will detail the basic findings and descriptions of each test pit, then discuss the architectural and linear features of each group, and finally compare these groups to one another and to the layout and patterning of the city of Cobá at large.

Most test pits were 1m x 1m, though some were expanded up to 2m x 2m. Because they were off-mound test pits, these excavations did not contain any floors or other architectural features (with one exception, a line of stones at the bottom of 201A). Thus, the profile drawings do not include the arbitrary 20cm level changes used for vertical control, in favor of simply the stratigraphic changes in soil/matrix composition. There were no lot changes within any level. Some profiles also depict an arbitrary thickness of bedrock or "roca madre" to square off the drawing; this was done for visual purposes only and not meant to indicate that we excavated through any bedrock. Most excavations were completed after finding bedrock throughout the excavation limits, with rare exceptions where deep pits in the bedrock made this near impossible.

7.3 Area 200 (Cenote Ya'axche)

Test pit 200A (Figure 7.2) was excavated just alongside a *cenote* we dubbed Ya'axche' for the enormous ceiba growing on its northeast end. The group to its immediate east (W1N1159) and the surrounding groups are positioned at the junction of a number of Sakbej 3, Sakbej 26, and several smaller *sakbej*. This created a nexus point for foot traffic and activities likely involving lime plaster production, market exchange, and residential living spaces, based on the types and placement of structures. To facilitate further movement off of the main *sakbej*, a network of *chichbe* and *t'úubulbej* links structures to the *cenote*, the *sakbej*, and to one another.

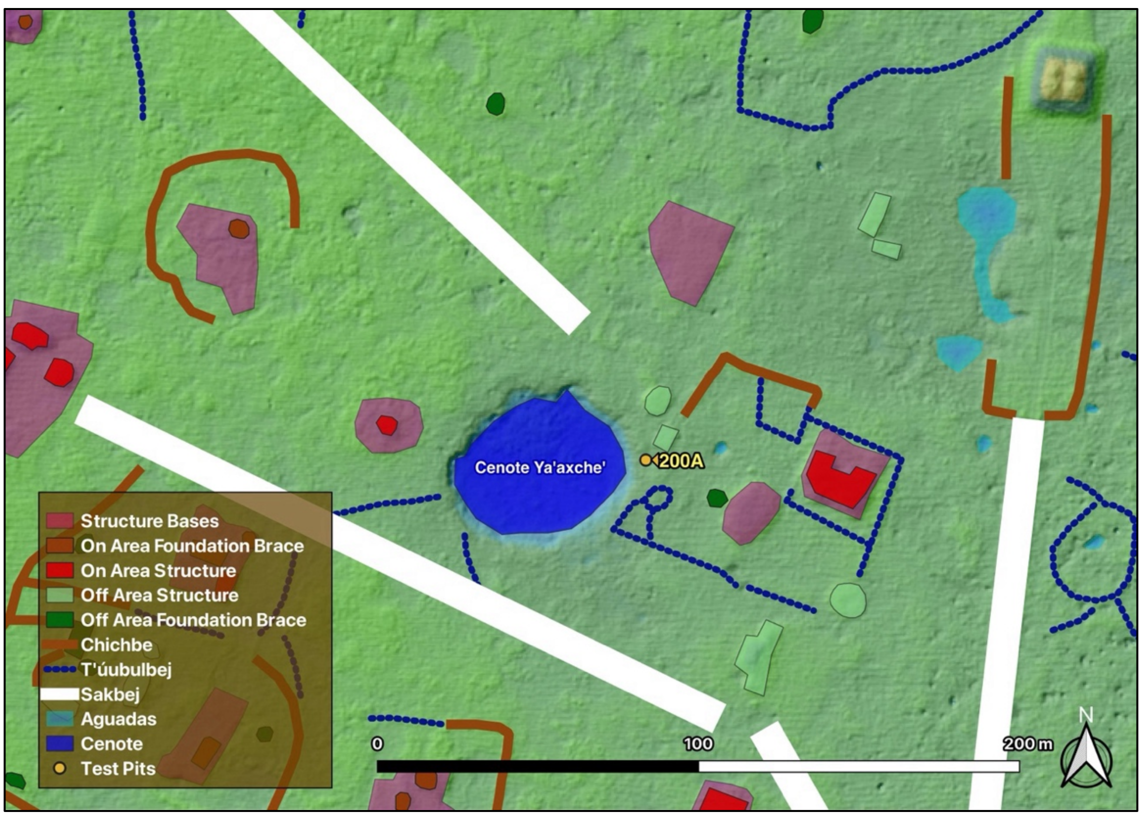

Figure 7.2 Cenote Ya'axche with Group W1N1159 and Unit CO200-A-1.

Importantly, the water level of Cenote Ya'axche' is very near the ground surface, and the contiguous area is a large natural depression relative to the greater surrounding expanse. Within this depression is a break in Sakbej 3 in the form of an elongated plaza and a large structure with a square base mounted by four rooms, a rather elaborate example of what Folan and colleagues (1983:155) refer to as toll booths. The area on either side of this "toll booth" is swampy and during the rainy season holds a significant amount of water in seasonal aguadas. Adjacent to this swampland, at slightly higher elevations, contemporary *milperos* grow watermelon, squash, and other crops, and access the area by a gravel and dirt road cleared directly atop Sakbej 3. It is therefore quite likely that past peoples utilized this area for agriculture - specifically fruit trees whose roots enjoy proximity to the water table, and perhaps cacao (Terry et al. 2022).

Agriculture would certainly not have been the only activity in this major confluence of *sakbej*. Large structures - some with vaulted roofs - were built at group W1N1159 and several other groups in this zone. At the southeast corner of group W1N1159 is an annular pitted structure which was likely a pit-kiln for lime production (see Seligson et al. 2017). Such pit-kilns would have required about 200 liters of water to produce each batch of lime, according to contemporary traditional production methods (Russell and Dahlin 2007:414), and thus they were often situated near water sources. They also required fuel in the form of greenwood from sources with high water content such as *chacah* and *chucum* (Russell and Dahlin 2007:412), which can be fast-growing but require ample water in order to do so. A *t'úubulbej* runs from this pit-kiln to the *cenote* to its west on one end, and north up and around the borders of the group on the other. A *chichbe* connects to the network of *t'úubulbej* on the northwest corner of the group. Along the inside of the *t'úubulbej* line on the south end, a pair of small oblong ditches in the limestone likely served as small reservoirs, while a larger such cavity is situated in the middle of the main courtyard to the northwest. If these small reservoirs were lined with lime plaster or *bajpéek* (a mixture of lime, *saskab*, and argillaceous soil), they could hold a considerable reserve of water through the dry season.

Figure 7.3 Photography of test pit excavation CO200-A-1.

The predominance of *olla* ceramic forms found within test pit 200A is also notable, but with several caveats. While some olla forms were for collecting, carrying, and storing water, others were used for food storage, cooking, or merely serving water. Furthermore, we must keep in mind that the relative size of *ollas* to other forms is much larger, and therefore the number and weight ratio of sherds towards *ollas* is expected to be greater. Still, it is reasonable to surmise that if the small reservoirs or miniature aguadas were unable to hold water through the dry season, the nearby *cenote* may have been utilized to refill them via short trips with *ollas*, thus increasing their representation in this area and others. The ceramic types place the group squarely within the Late Classic Period, during the height of Cobá's growth and power.

Ceramic Type	200A	201B	202A	203A	205A	207A	210A	210B	220A	220B	221A	221B	230A	230B	231A
Vista Alegre Estriado	3	16		3	25	43	16	19	3	33	5	5	22	9	
Sacalum: Gris						2									
Holactún negro sobre crema			2												
Encanto estriado: Sacná	5	66			14	30	4	94	7						8
Saxché Naranja Polícromo											2				
Muna: Cafetoso	4	4			2	6		2		13	2			1	
Arena Rojo	2	5	6	1	3	11		6	3		1				
Batres Rojo		4	1	2				1			1				
Lakin impreso compuestos		1			1			3							
Dos caras estriado				1				10							
Cetelac Desgrasante Vegetal			10	1		2		2	1	2					
Saban sin engobe: Becoob											8				
Joventud Rojo: Nolo											1				
Huachinango Bicromo-Inciso			1								1				
Chancenote Estriado								1							
Tancah Burdo					7						27	2			
Kuche								1							
Erosionados	9	11	7	4	16	29		53	10	16	23				
No Identificado						2									
Tejos	1				1										

Table 7.1 Numbers of ceramic sherds by type recovered from test pit excavations. The top first three types in gold are Oro Complex, the subsequent seven in green are Palmas, the next two in white are Blanco, the following four in orange are Añejo, and the single Kuche sherd dates to around 600-350BC.

Unit CO200-A-1. Dimensions: 1m x 1m. Group: Cenote Ya'axche (Figure 7.2).

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -31, NE: -24, SE: -26, SW: -37, C: -31cm from datum. No archaeological materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -50, NE: -51, SE: -50, SW: -51, C: -54cm from datum. Matrix was composed of very dark brown earth (7.5YR 2.5/2). The consistency of the earth is heterogeneous and contains roots and other organic material (leaves, fruits, etc.), and small stones. Near the bottom of the level there is a large root, and a large stone to the south end of the excavation. Ceramic material was found at this level of types Muna Cafetoso, Arena Rojo, and Encanto Estriado Sacná (Figure 7.4, see Table 7.1), placing it within the Robles' (1990) Palmas and Oro complexes, both of which correspond to Late Classic Period. The majority of ceramic forms were *ollas* and *tecomates* (semi-closed bowls).

Figure 7.4 Ceramic sherds from 200A, Level 2, Lot 1.

Level 3, Lot 1: 20-40cm. New level after 20cm, to NW: -65, NE: -57, SE: -70, SW: -64, C: -65cm from datum 0. Similar to level 2, very dark brown earth almost black (7.5YR 2.5/2). Bedrock was found in most of the excavation, except for the SE corner. Ceramic material was found at this level of types Muna Cafetoso, Arena Rojo, and Encanto estriado Sacná (Table 7.1), placing it within the Late Classic Period. *Ollas* were the only form of ceramic found at this level.

Level 4, Lot 1: 40-60cm. New level to expose bedrock in the SE corner (where there is a hole in the bedrock), at NW: -65, NE: -57, SE: -95, SW: -64, C: -65cm from datum. The ground was wet and slightly lighter brown than the levels above (7.5YR 3/3). Some small stones were found just before reaching bedrock, which was fully exposed to complete the excavation of the unit. No archaeological materials were recovered at this level.

7.4 Area 201 (Kitamna)

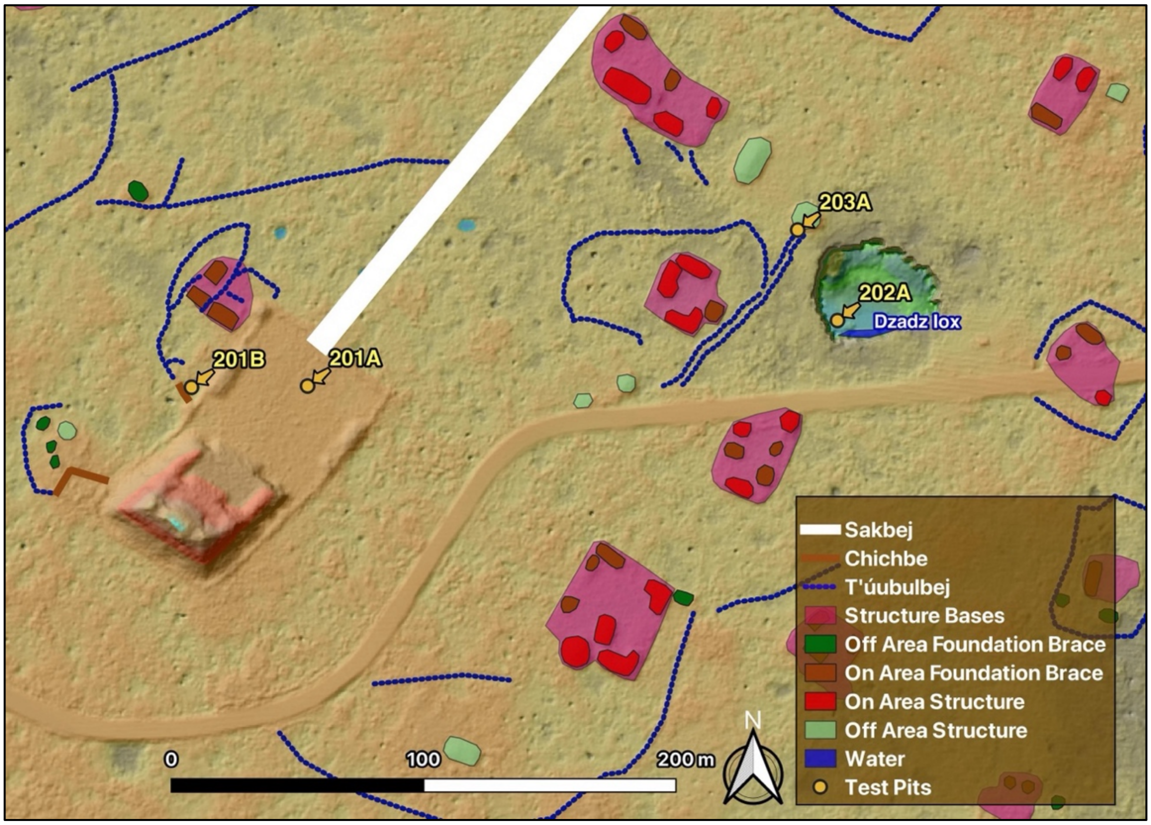

Figure 7.5 Map of Kitamna and Dzadz Iox, with locations of test pits 201A, 201B, 202A, and 203A.

Test Units CO201A & CO201B (Figure 7.5) supply us with a glimpse into life at this grand *sakbej* termini complex, Kitamna. The dry-core fill with almost no artifacts in 201A is expected in the cases of a central plaza built up in few construction phases to create the large plaza on which to build the complex and speaks to the lack of (or sparse) occupation in this arear prior to the raising of this plaza. Test pit 201B by contrast was loaded with artifacts, as it was placed on a prospective midden, a small bump in the jungle just off of some small structures, including one of the long buildings on the west edge of the plaza, a perfect spot for a trash pit. Finding seashells used for jewelry (mother of pearl) and already formed shell jewelry (spondylus shell earspool) is also expected for the elite status of the occupants of Kitamna. The bulk of the ceramic material here was again sherds from *ollas*, perhaps related to the nearby *ts'aats'*. Some of the types found (mostly Encanto Estriado: Sacná, and Arena Rojo) also are Late Classic, but importantly here we also find a substantial amount of Vista Alegre Estriado, dating to the Terminal Classic and Early Postclassic, roughly 850-1100AD (Kepecs 1998; Rissolo and Glover 2007; Robles Castellanos 1990), a time of population decline at Cobá likely caused by the crises of droughts, to be discussed further in the ensuing chapter. Not far away, the associated *ts'aats'* and wider area around the Kitamna terminus provide more context, where we excavated Units CO202A and CO203A, further discussed below.

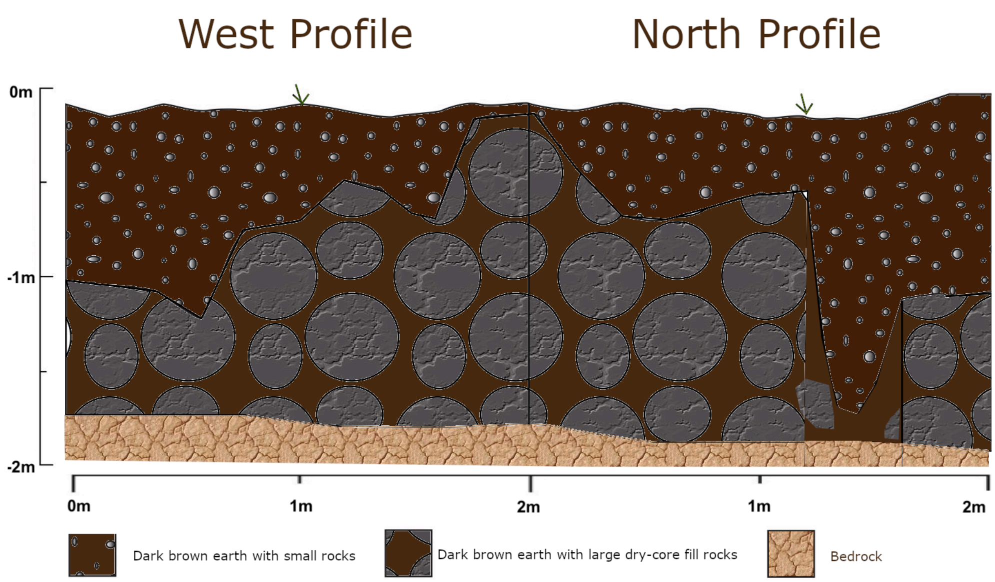

Figure 7.6 Profile of test pit CO201-A-1.

Unit CO201-A-1. Dimensions: 2m x 2m. Group: Kitamna (Figures 7.5 and 7.6).

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -3, NE: -2, SE: 0, SW: -4.5, C: -3cm from datum. No archaeological materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -23, NE: -23, SE: -23, SW: -23, C: -22cm from datum. Matrix was composed of very dark brown earth (7.5YR 2.5/3) mixed with thin roots and small stones. Near the base of the level were medium stones. No archaeological materials were recovered at this level.

Level 3, Lot 1: 20-40cm. New level after 20cm, to NW: -64, NE: -47, SE: -65, SW: -60, C: -60cm from level from datum 0. The ground was still very dark brown (7.5YR 2.5/3), but with medium and large stones (~35cm) of the "dry-core fill" type. No archaeological materials were recovered at this level.

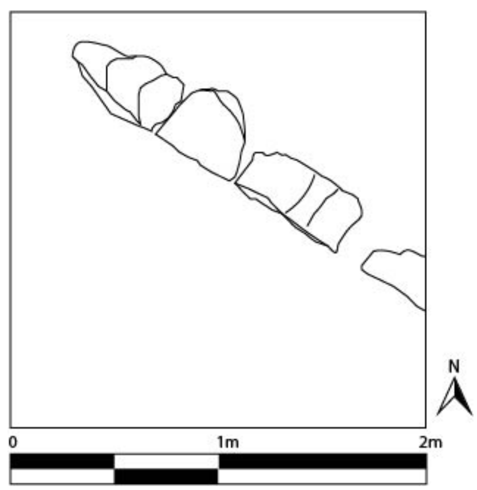

Figure 7.7 Plan drawing of test pit 201A, Level 4, Lot 1.

Level 4, Lot 1: 40-60cm. Excavated to expose bedrock, which was NW: -64, NE: -47, SE: -85, SW: -77, C: -80cm from datum. The soil was slightly lighter brown than the levels above (7.5YR 2.5/2), but most of the matrix was dry core fill. A line of facing stones was found (Figure 7.7), following from one corner of the excavation to the other. Bedrock was also found in almost all of the pit. Sparse ceramic material was recorded (Figure 7.8) and the level and excavation of this pit was closed.

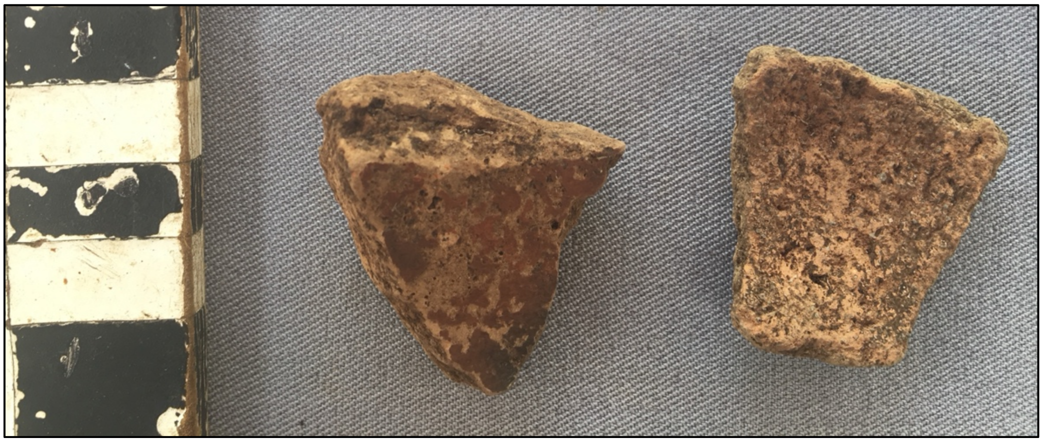

Figure 7.8 Ceramic sherds from test pit 201A, Level 4, Lot 1.

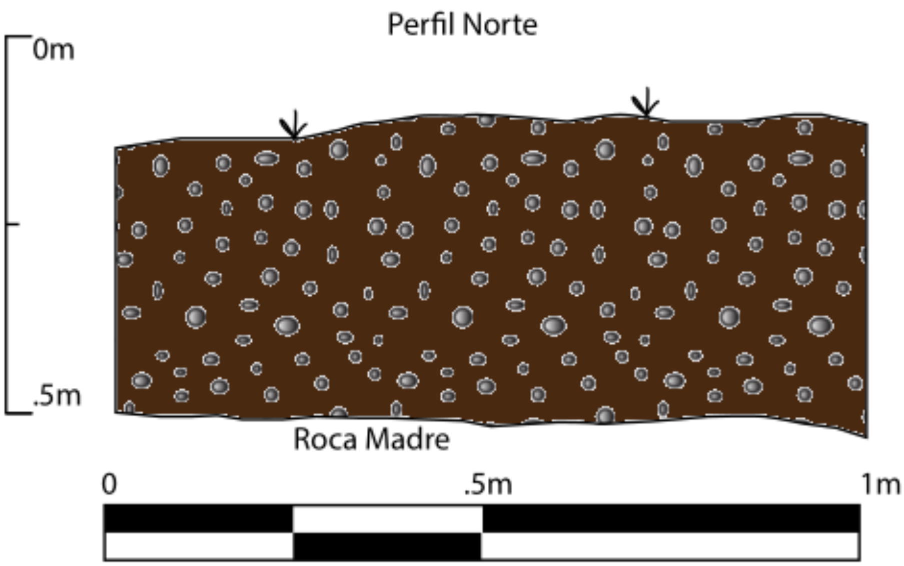

Figure 7.9 Profile of test pit CO201-B-1.

Unit CO201-B-1. Dimensions: 1m x 1m. Group: Kitamna (Figure 7.5).

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -16, NE: -10, SE: -10, SW: -9, C: -11cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -36, NE: -29, SE: -30, SW: -29, C: -31cm from datum. The matrix was dense with artifacts - possibly a midden. It was composed of a very dark brown earth (7.5YR 2.5/3) with many roots and some small stones. Abundant ceramic materials (mostly Encanto Estriado Sacná *ollas*, Figure 7.10), and also some shell, obsidian, and chert materials were found at this level.

Figure 7.10 Ceramic sherds from test pit 201B, Level 2, Lot 1.

Level 3, Lot 1: 20-40cm. New level after 20cm, to NW: -50, NE: -53, SE: -56, SW: -56, C: -54cm from level from datum 0. Similar to level 2, very dark brown earth almost black (7.5YR 2.5/2). Bedrock was found in almost all of the excavation. Again, copious ceramic and marine shell material were found at this level, including an intact large sea snail shell and a spondylus ear spool (Figure 7.11).

Figure 7.11 Shell material recovered from test pit 201B. a) Spondylus shell carved into jewelry (ear spool or bead); b) West Indian top shell (*Cittarium pica*), an edible sea snail whose inner shell forms nacre.

7.5 Area 202 (Dzadz Iox)

Although we did not obtain a great number of ceramic sherds from Unit 202A (Figure 7.5) itself, that test pit was very near the water of the *ts'aats'*, and a wealth of sherds were collected from along its bank, the vast majority of which (183/199 sherds collected) were from *ollas*, while the majority of the types were Arena Rojo (126) and Batres Rojo (36), indicating Late Classic occupation. Also, the monkey figurine head (see below) was an exciting and important find, likely connected to the cultivation of cacao in the *ts'aats'*, to be discussed more in the following chapter.

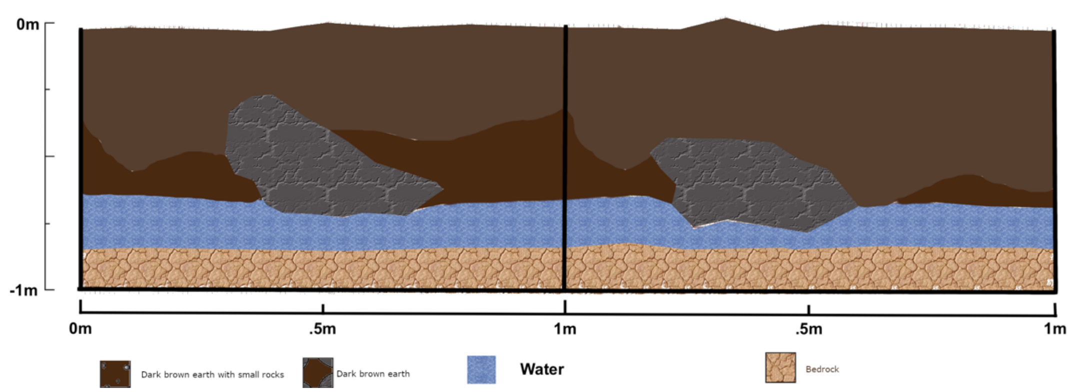

Figure 7.12 Profile of test pit CO202-A-1.

Unit CO202-A-1. Dimensions: 1m x 1m. Group: Dzadz Iox (Figure 7.5).

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: 3, NE: 3, SE: 0, SW: 3, C: 1cm from datum. No archaeological materials were recovered at this level.

Figure 7.13 Fragment (head) of a ceramic monkey figurine found in test pit 202A, Level 2, Lot 1.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -17, NE: -23, SE: -19, SW: -20, C: -20cm from datum. Matrix was composed of very dark brown soil (10 YR 2/2) that was wet from the proximity of a *ts'aats'*, and from the rain on this day. Many ceramic materials (including a piece of a monkey head figurine, Figure 7.13), and a piece of chert found at this level.

Level 3, Lot 1: 20-40cm. New level after 20cm, to NW: -42, NE: -30, SE: -19, SW: -29, C: -21cm from level from datum 0. Similar to level 2, very dark brown soil almost black (7.5YR 2.5/3), and wet. Water table reached ~35cm below datum 0. We used a stick to approximate depth to bedrock, ~12cm below water level. Level and excavation closed.

Ceramic material was recorded at this level, mainly Encanto Estriado Sacná *ollas* (Figure 7.14).

Figure 7.14 Ceramic sherds from test pit 202A, Level 3, Lot 1.

7.6 Area 203 (Dzadz Iox adjacent)

Unit 203A contained the only human bone found in this season of test pit excavations, and human bone in general is a relatively rare find at Cobá, though this is likely in part due to the fact that many of the monumental structures remain unexcavated. The skeletal material consisted of only a few fragments found in shallow soil. Despite this context that provides limited information, the mere presence of human bone near both a large structure and the *ts'aats'* emphasizes the sacrosanct ritual setting of this area, again near the Kitamna terminus.

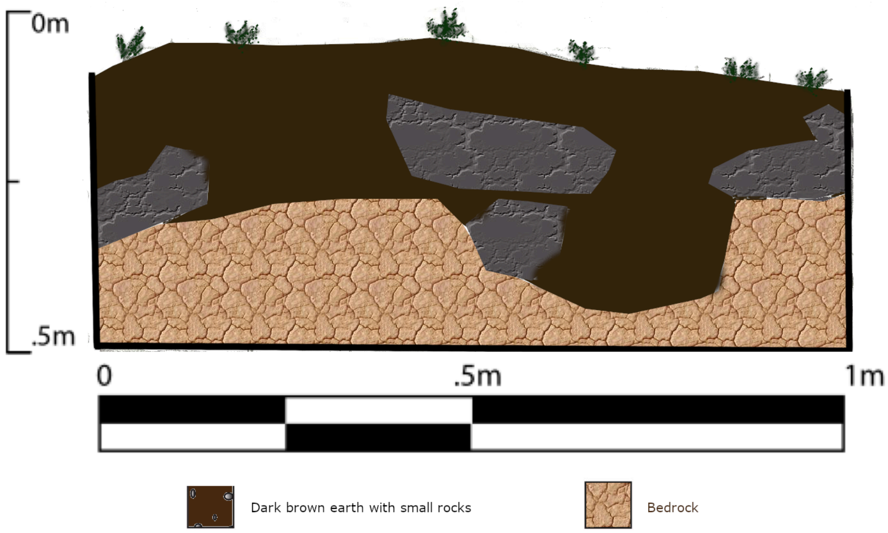

Figure 7.15 Profile of test pit 203-A-1.

Unit CO203-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -6, NE: 6, SE: 0, SW: 0, C: 7cm from datum. No archaeological materials were recovered at this level.

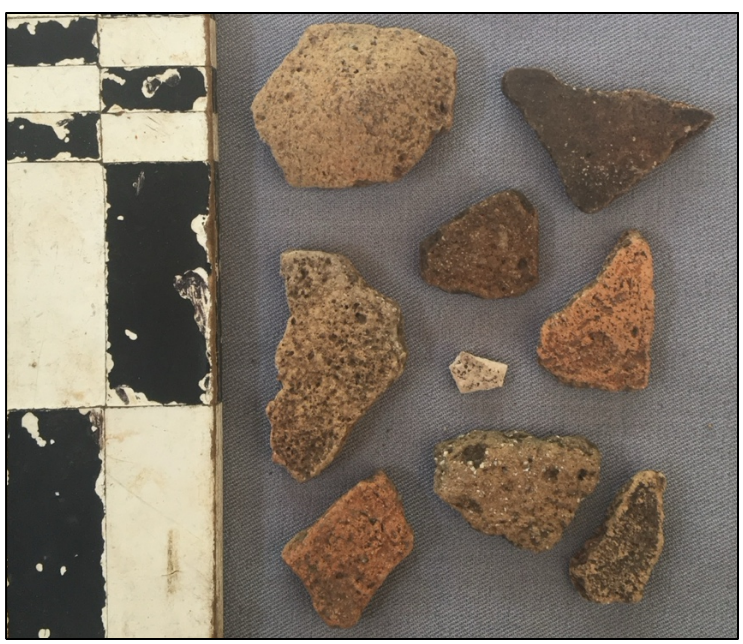
Figure 7.16 Ceramic sherds from test pit 203A, Level 2, Lot 1.

Level 2, Lot 1: Excavated down to NW: -17, NE: -10.5, SE: -19, SW: -24, C: -27cm from datum. Matrix was composed of very dark brown earth (10 YR 2/2), with small stones and roots (and insects). The soil was shallow, and bedrock was found throughout the excavation before 20cm depth from humus. Ceramic materials (Late Classic, Figure 7.16), obsidian, and some human bone fragments (Figure 7.17) were found at this level.

Figure 7.17 Fragments of human bone from test pit 203A, Level 2, Lot 1.

7.7 Areas 205 & 207 (near Dzadz Ion)

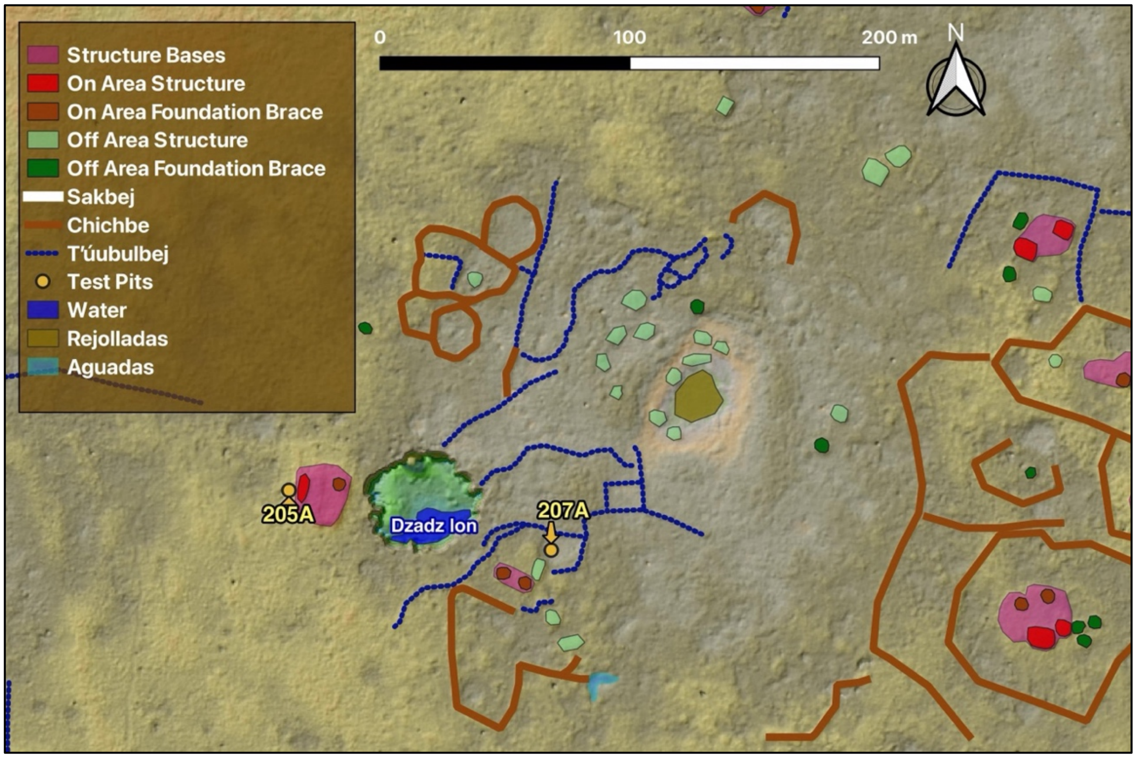

Figure 7.18 Map of Dzadz Ion with locations of test pits 205A and 207A.

Units 205A and 207A are near groups on either side of Dzadz Ion. Unit 205A is of particular interest, as its Tancah Burdo ceramics indicate Preclassic activity associated with Dzadz Ion, which currently contains cacao, ramon, mamey, and avocado trees (Terry et al. 2022:4). Previous excavations within Dzadz Ion also recovered fragments of Late Postclassic Chen Mul *incensarios* including ceramic cacao pods (Terry et al. 2022:11), indicating the *ts'aats'* was still recognized as a sacred cacao grove long after the might of Cobá had waned, though by a much-diminished population, perhaps merely a trickle of pilgrims or traders passing through and making offerings while harvesting the riches still growing down below. The group associated with 205A is situated along the western edge of Dzadz Ion on a raised platform with stairways and well-constructed stone walls delineating rooms with stone benches. Three *metates* were also found within and around this group.

Unit 207A was shallow and contained fewer archaeological materials, but its group and other groups explored to the north and northeast of this are remarkable for their many *t'úubulbej* and *chichbe* that often bleed into one another, forming a continuum of walkways around many small structures, a phenomenon that heavily influenced the direction of this research. A small *rejollada* to the northeast of Dzadz Ion and other depressions and low-lying ground in the area are likely stimuli for the density of the linear features here, a probable nexus for agricultural production beyond the *ts'aats'*.

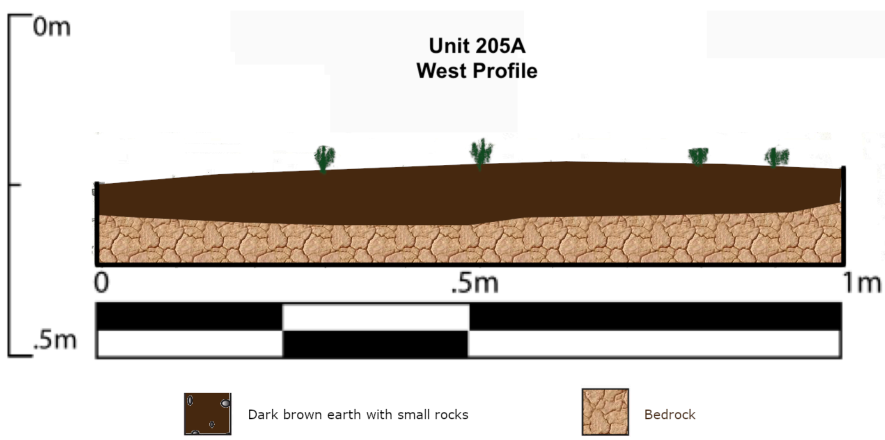

Figure 7.19 Profile of test pit CO205-A-1.

Unit CO205-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -4, NE: -6, SE: -0, SW: -10, C: -1cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -10, NE: -17, SE: -17, SW: -14, C: -11cm from datum. Matrix was composed of very dark brown earth (10 YR 2/2), with stones (some orange due to oxidation) and small roots (and insects). The soil was shallow, and bedrock was found throughout the excavation before 20cm depth from humus. Ceramic materials, shell, and chalk were found at this level. Amongst the common Late Classic ceramic sherds, some (7) Tancah Burdo sherds were recovered (7.20), part of the Añejo Complex according to Robles (1990).

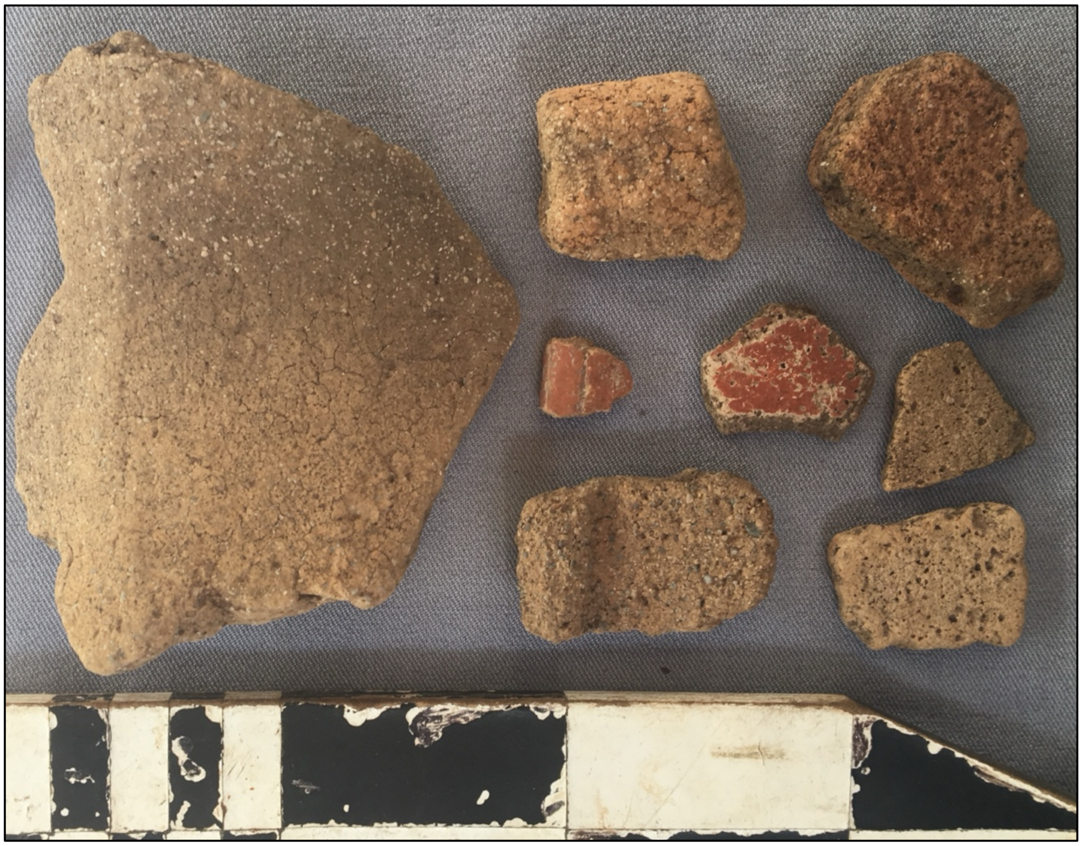

Figure 7.20 Ceramic sherds from test pit 205A, Level 2, Lot 1.

Unit CO207-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -20, NE: -22, SE: -26, SW: -17, C: -10cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -36, NE: -29, SE: -37, SW: -35, C: -32cm from datum. Dark brown (10 YR 2/2) soil was shallow, and we reached bedrock quickly throughout unit. Despite this, we recovered a mass of ceramic sherds, and one fragment of an obsidian blade.


Figure 7.21 Ceramic sherds and fragments from test pit 207A, Level 2, Lot 1.

7.8 Area 210 (Cenote Sinacal)

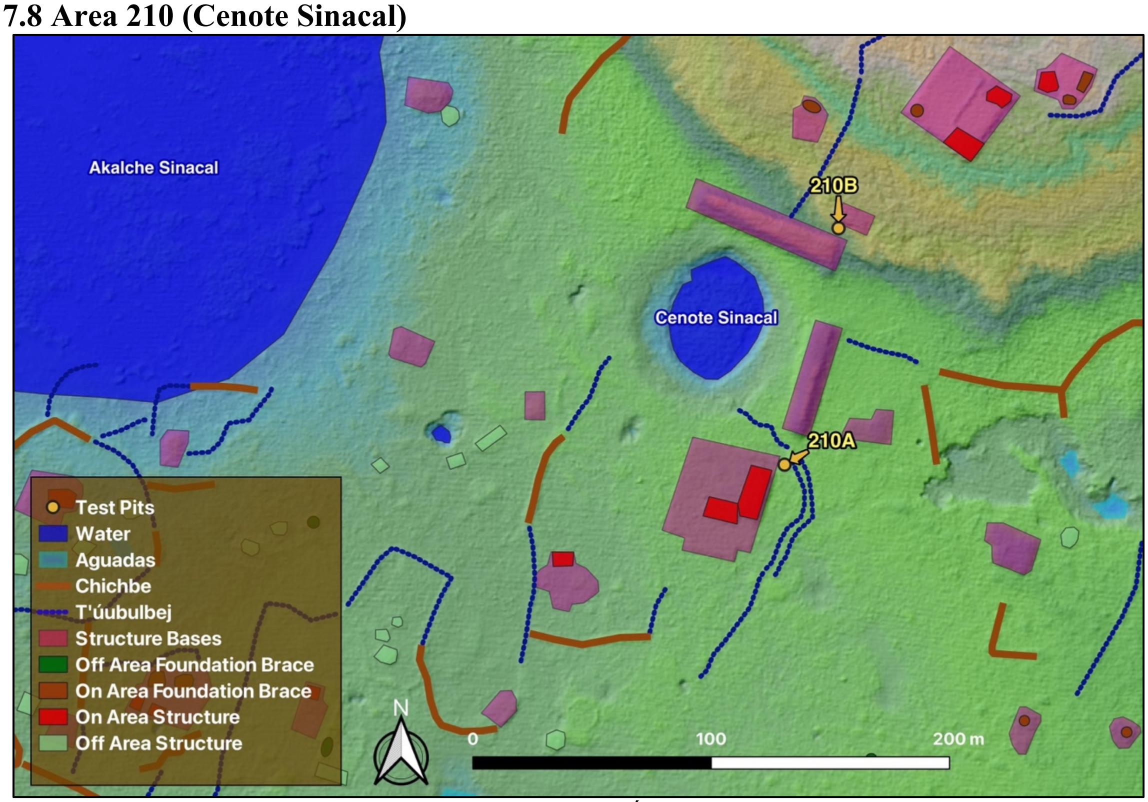

Figure 7.22 DEM map of Cenote Sinacal, near Sinacal Áak'alche', with locations of 210A and 210B.

Test pit 210A was placed between a large, raised complex and a ranged structure south and east of a *cenote* we dubbed Cenote Sinacal for its proximity to Sinacal Áak'alche'. The soil was much deeper and seemingly richer than most of the other test pit areas. Unit 210B was excavated behind the north ranged structure, between it and another structure with sturdy walls of large stones, bordering on megalithic. A Kuche painted and modeled rim sherd was uncovered in the lowest level of 210B, signifying an early start to occupation there between 600-350BC (Andrews V 1988; Bey III et al. 1998; Rissolo et al. 2005). A large swath of land to the south of Sinacal Áak'alche' was likely a prime agricultural zone, as it is low-lying with many aguadas and depressions for runoff while also comprising many *chichbe* and *sakbej*-walls that could be used to build up soil in certain areas and retain or direct water to the same. The positioning of the ranged structures and raised complex around Cenote Sinacal, then, may have not only capitalized on this water source, but also the positioning between this swath of agricultural land to its southwest and the centralized urban areas and markets of Cobá to its north with grand complexes, especially the nearby Macanxoc group.

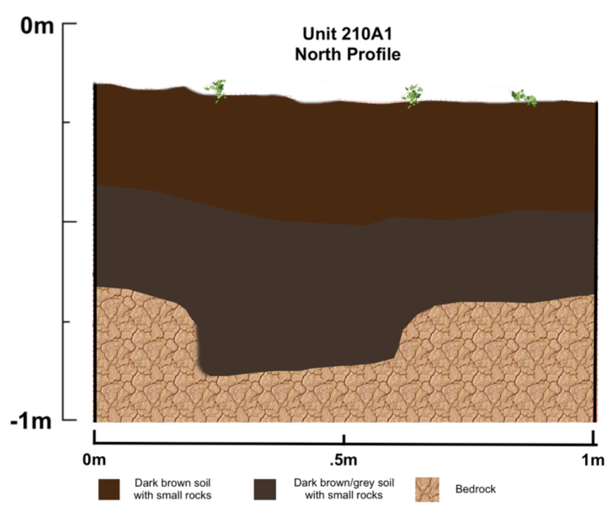

Figure 7.23 Profile of test pit CO210-A-1.

Unit CO210-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -24, NE: -14, SE: -17, SW: -29, C: -17cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -43, NE: -42, SE: -41, SW: -41, C: -42cm from datum. The matrix was composed of a very dark brown earth (10 YR 2/2), with many stones and small roots, and one large root. Ceramic materials (Figure 7.24), fossilized shell, chert, a fragment of obsidian, and cinnabar were found at this level.

Figure 7.24 Ceramic sherds from test pit 210A, Level 2, Lot 1.

Level 3, Lot 1: 20-40cm. New level after 20cm, to NW: -61, NE: -59, SE: -60, SW: -60, C: -61cm from level from datum 0. Similar to level 2, very dark brown earth but somewhat grayer (7.5YR 3/2), and wet, with many stones and small roots and some medium stones. Ceramic material (Figure 7.25) was recorded at this level, but slightly less than level 2.

Figure 7.25 Ceramic sherds from test pit 210A, Level 3, Lot 1.

Level 4, Lot 1: 40-60cm. New excavation level 20cm after the one above was excavated up to some very large stones (like slabs, but not cut), NW: -67, NE: -65, SE: -66, SW: -60, C: -63cm from datum. The ground was dark brown and gray (7.5YR 3/2). The level was closed by the big stones. Only a single ceramic sherd was found at this stratum.

Level 5, Lot 1: 60-80cm. New level to expose bedrock (after large stones were removed), at NW: -81, NE: -66, SE: -78, SW: -77, C: -63cm from datum. The ground was slightly lighter brown than the upper levels, with more gray (7.5YR 4/2). Sascab found in the northern part of the excavation, and bedrock throughout the rest of the pit. No archaeological materials were recovered at this level.

Unit CO210-B-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -5, NE: -11, SE: -19, SW: -13, C: -15cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Opened test pit NE of ranged structure north of Cenote Sinacal, and just south of tall, large platform with megalithic south wall. Dug down to NW: -28, NE: -28, SE: -35, SW: -32, C: -15cm from datum. Dark brown soil (10YR 2/2), many small rocks and roots, and one medium to large rock in middle southwest of unit, and another in the wall. Ceramic sherds, obsidian blade fragments, and shells were recovered from this level.

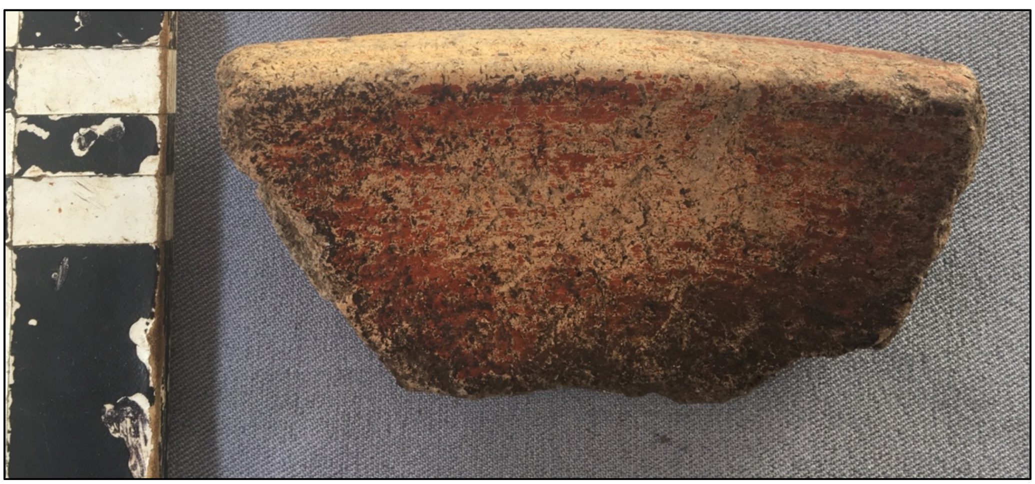

Figure 7.26 Kuche rim sherd from test pit 210B, Level 3, Lot 1.

Level 3, Lot 1: 20-40cm. New level after 20cm from above, but soon hit bedrock at NW: -43, NE: -38, SE: -43, SW: -40, C: -42cm from datum. Many ceramic sherds recovered, including a large painted and modeled rim sherd (Figure 7.26) found just atop bedrock near the northeast corner of unit. Similar dark brown soil (10YR 2/2) with small roots and rocks throughout. Unit closed.

7.9 Area 220 (Cenote Corcho)

Figure 7.27 DEM map of the Nojoch Mul group, Cenote Corcho, and Units 220A and 220B.

For the 220 area we return to the core of Cobá, near the massive structures of the Nojoch Mul complex and alongside a *cenote* dubbed Cenote Corcho for the use of fallen wood there to be used for cork material. Somewhat surprisingly, the 220A and B test pits here did not uncover much resembling elite goods, as did the excavation near Kitamna. The structures along the *cenote* and near the 220 units were not remarkable themselves, but they are not all that far away from the aforementioned largest structures in Cobá. Perhaps this area was populated by lower class water porters, and the elites did not reside along the banks of a *cenote* such as this one, which today is very buggy and not especially welcoming for a swim or bath. While its water table is quite close to the surrounding land surface, the water body resembles a swamp more than a picturesque *cenote* of clear cool water. Presumably it was better managed in past eras, but then again it also had to contend with population pressures.

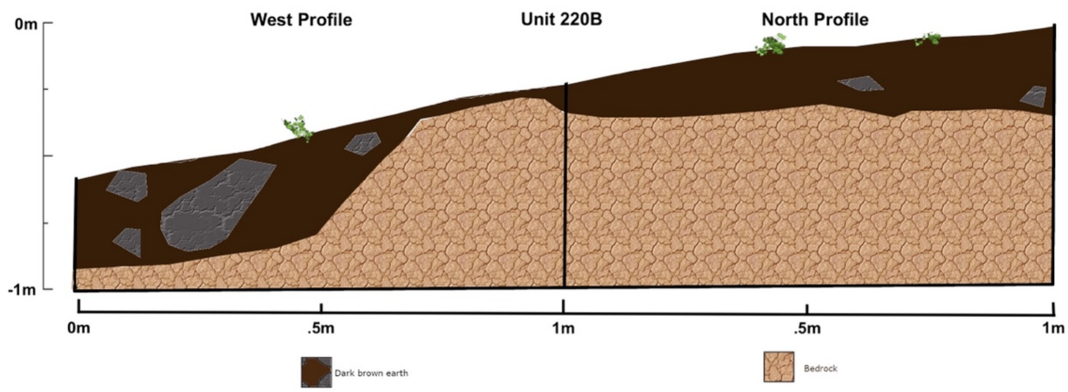

Figure 7.28 Profile of test pit CO220-B-1.

Unit CO220-B-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -5, NE: 4, SE: -17, SW: -24, C: -12cm from datum. No archaeological materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -15, NE: -22, SE: -30, SW: -43, C: -39cm from datum. Matrix was composed of very dark brown earth (10 YR 2/2), with many stones and small roots, and some medium and large stones on the bedrock. The soil was shallow, and bedrock was found throughout the excavation before 20cm depth from humus. Late Classic ceramic materials were found at this level, mostly Vista Alegre Estriado *tecomates* and Muna Cafetoso *ollas* (Figure 7.29).

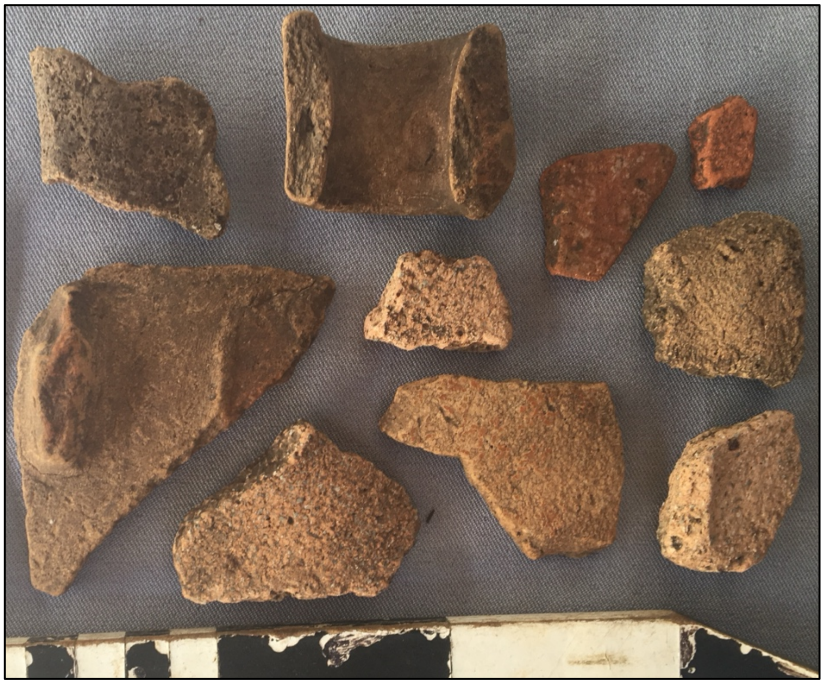

Figure 7.29 Ceramic sherds from test pit 220B, Level 2, Lot 1.

7.10 Area 221 (San Pedro)

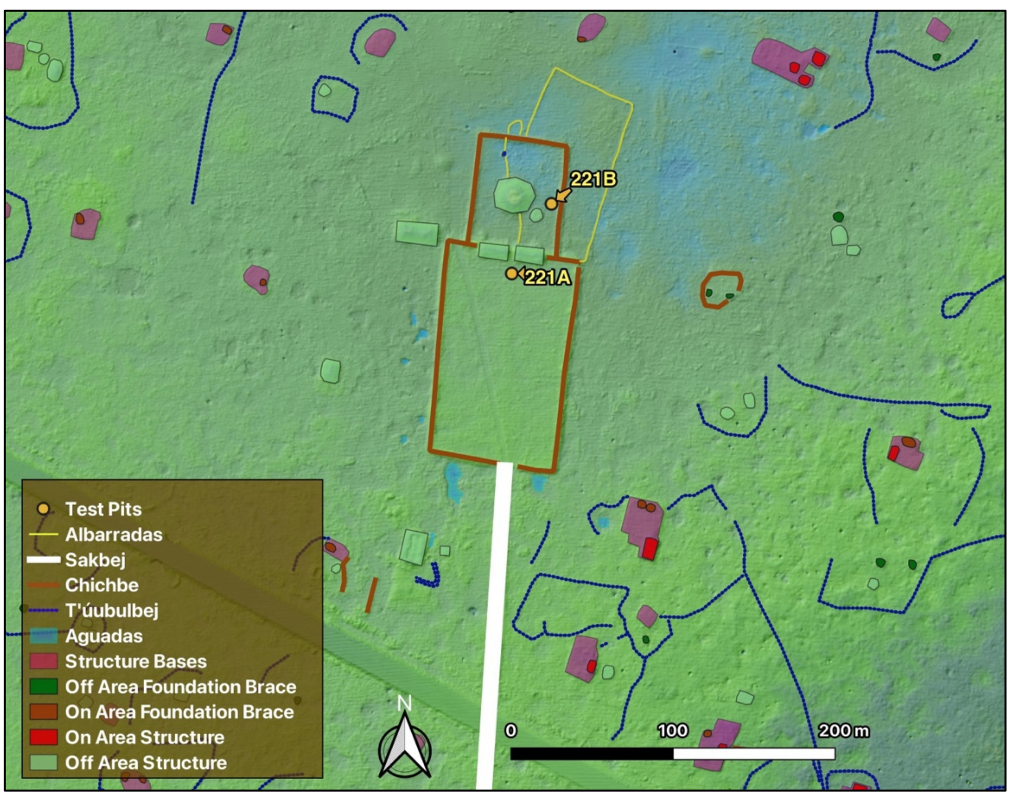

Figure 7.30 DEM of San Pedro terminus with test pits 221A and 221B.

The CO221A & B test pits were situated amongst a highly fascinating group known as San Pedro, the terminus complex of Sakbej 3. North and east of this terminus are very low-lying areas that are easily flooded even relative to the many other flood-prone regions of Cobá. There are a few small windows to the aquifer known as *ch'e'en*, or wells, one of which sits inside the main northern plaza of San Pedro, northwest of the conical structure in its center. Another well, with modern accoutrements, sits just beyond the plaza further northwest, and the surrounding area is today a ranch with horses, cows, goats, citrus, and other agriculture, as it likely served in the ancient past (minus the citrus and Old-World animals, of course). Of note, Unit 221A was the only test pit of mine to contain sherds of type Becoob, which on Robles' (1990) schema fit at the very end of the Preclassic Period. Tancah Burdo sherds, likewise Preclassic, were also uncovered from units 221A and B.

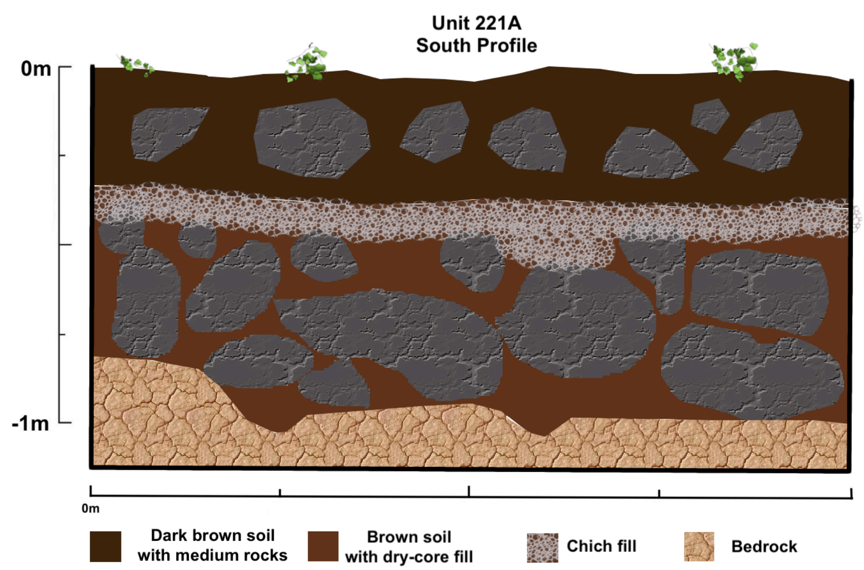

Figure 7.31 Profile of test pit CO221-A-1.

Unit CO221-A-1. Dimensions: 2m x 2m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -24, NE: -14, SE: -12, SW: -17, C: -22cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -42, NE: -33, SE: -30, SW: -33, C: -41cm from datum. Matrix was composed of very dark brown earth (7.5 YR 2.5/3), with many small stones and roots, and some medium stones. Ceramic materials were found at this level, mostly Tancah Burdo *macetas* (Figure 7.32).

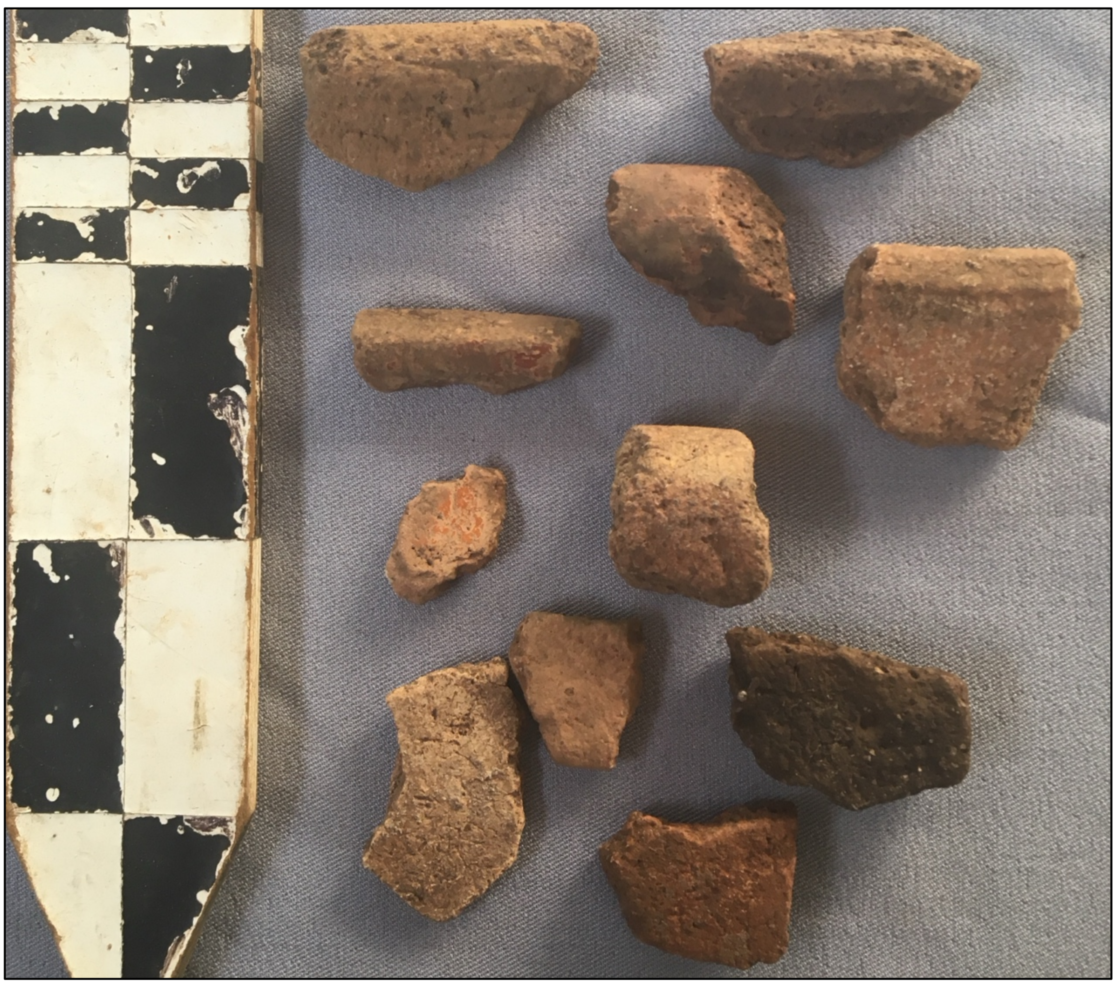

Figure 7.32 Ceramic sherds from test pit 221A, Level 2, Lot 1.

Level 3, Lot 1: 20-40cm. New level after 20cm, to NW: -61, NE: -65, SE: -61, SW: -60, C: -63cm from level from datum 0. Similar to level 2, brown earth but somewhat lighter (7.5YR 4/4), and with more medium stones, but also *ch'ich'* small stones. There seemed to be a floor in profile, but of very poor construction. Ceramic material was recorded at this level.

Level 4, Lot 1: 40-60cm. New excavation level 20cm after the one above was excavated up to NW: -89, NE: -97, SE: -87, SW: -98, C: -92cm from level of the datum 0. The soil was brown (7.5YR 4/4), but most of the level was dry core fill construction, including a large rock in the center of the pit. No cultural materials were recovered at this level.

Figure 7.33 Ceramic sherds from test pit 221A, Level 5, Lot 1.

Level 5, Lot 1: 60-80cm. New excavation level after ~20cm, to NW: -118, NE: -105, SE: -110, SW: -110, C: -121cm from datum. The soil was brown (7.5YR 4/4), but most of the matrix at this level was also dry core fill, but with more *ch'ich'* fill. Bedrock was found in the southeastern part of the excavation. Ceramic sherds of Tancah Burdo *macetas* and one of Joventud Rojo *cajete* (Figure 7.33) were recorded at this level.

Level 6, Lot 1: 80-100cm. New level to expose bedrock (in the center of the pit at least, where it was safe to do so without cave-in), at NW: -131, NE: -118, SE: -112, SW: -132, C: -138cm from datum. The ground was dark reddish brown (5YR 3/4). Ceramic material was recorded at this level. Unit closed.

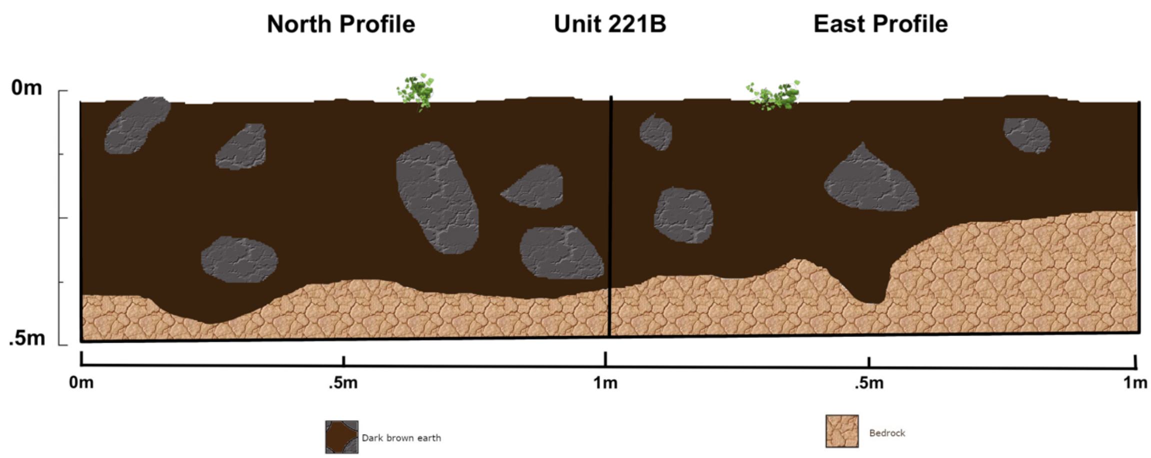

Figure 7.34 Profile of test pit CO221-B-1.

Unit CO221-B-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -21, NE: -20, SE: -21, SW: -21, C: -20cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -50, NE: -39, SE: -42, SW: -31, C: -47cm from datum. Matrix was composed of very dark brown earth (7.5 YR 2.5/3), and wet. Bedrock was found to the south of the excavation. A few ceramic sherds of Vista Alegre Estriado (Figure 7.35) were found in this stratum.

Figure 7.35 Ceramic sherds from test pit 221B, Level 2, Lot 1.

Level 3, Lot 1: New level to expose bedrock in the remainder of the pit, at NW: -63, NE: -57, SE: -42, SW: -31, C: -54cm from datum. The soil at this level was dark reddish brown (5YR 3/4), and wet with medium stones. A few sherds of Tancah Burdo *macetas* (Figure 7.36) were found in this stratum.

Figure 7.36 Ceramic sherds from test pit 221B, Level 3, Lot 1.

7.11 Areas 230 & 231 (Kubulte)

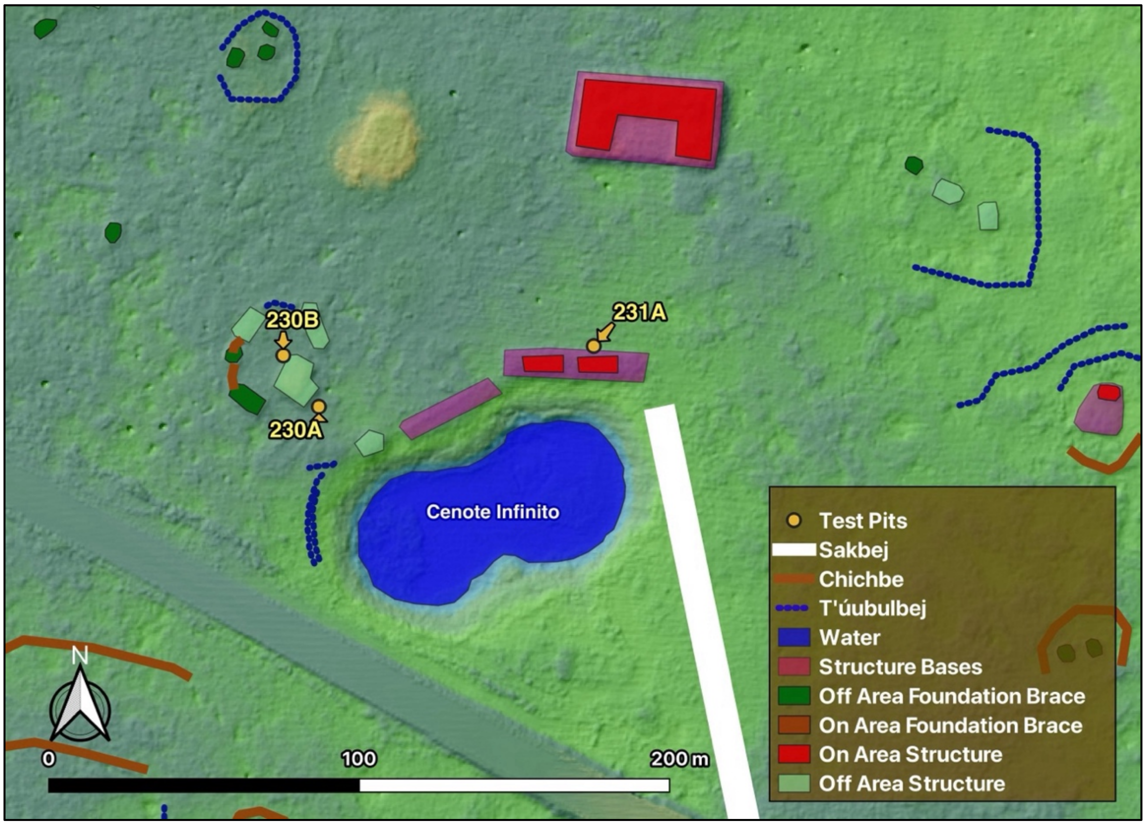

Figure 7.37 DEM map of Sakbej 26 terminus at Cenote Infinito, with units 230A, 230B, and 231A.

The 230 and 231 test pit units were placed near structures surrounding a *cenote* dubbed Cenote Cacahuate (for its peanut shape) at a *sakbej* terminus. Unlike many of the other *sakbej* termini, this *sakbej* comes directly to the edge of a *cenote*. While there is a faint trace of a continued road that bends slightly and ends at a larger complex a bit further north with multiple vaulted rooms, even that does not have a grand raised plaza area and is not as imposing as most of the other *sakbej* termini complexes, like Kitamna and Kukikan. Instead, here the focus is more on the ranged structures facing the *cenote*, and the cluster of small structures behind them. Even the larger structure to the north is oriented more towards the *cenote* than the entrance angle of the *sakbej*, again underlining that water source as the main attraction of this area. Interestingly, the 230A and B test pits near the cluster or circle of small buildings contained almost exclusively Vista Alegre Estriado ceramic sherds, while the 231A unit behind the larger ranged building not far away to the east contained exclusively Encanto Estriado Sacná sherds. While the chronology of these types overlaps and therefore does not necessarily point to markedly different temporal occupations, it may instead highlight a difference in distribution systems and perhaps class differences between the occupants of these nearby groups.

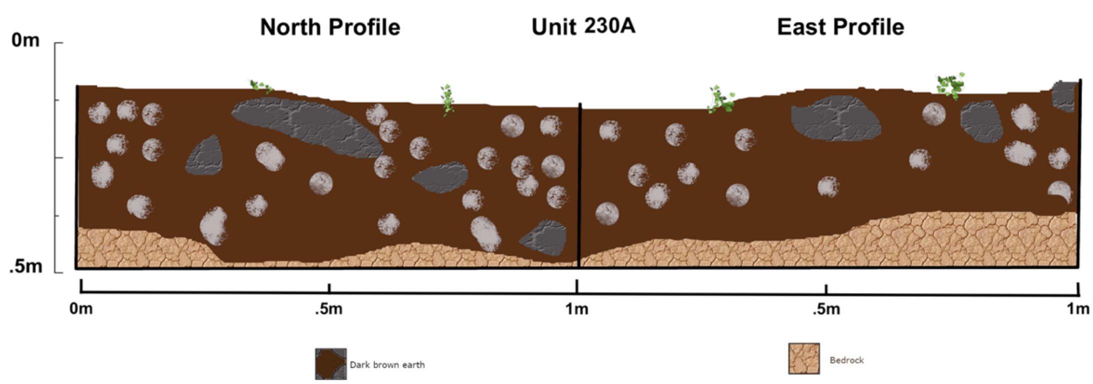

Figure 7.38 Profile of test pit CO230-A-1.

Unit CO230-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -14, NE: -16, SE: -13, SW: -12, C: -11cm from datum. No archaeological materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -40, NE: -40, SE: -41, SW: -36, C: -34cm from datum. Matrix was composed of dark brown earth (7.5 YR 3/4), with many roots and small stones, and some medium stones. Bedrock was found in the southern part of the excavation. Vista Alegre Estriado *tecomate* ceramic sherds (Figure 7.39) and two obsidian fragments were found at this level.

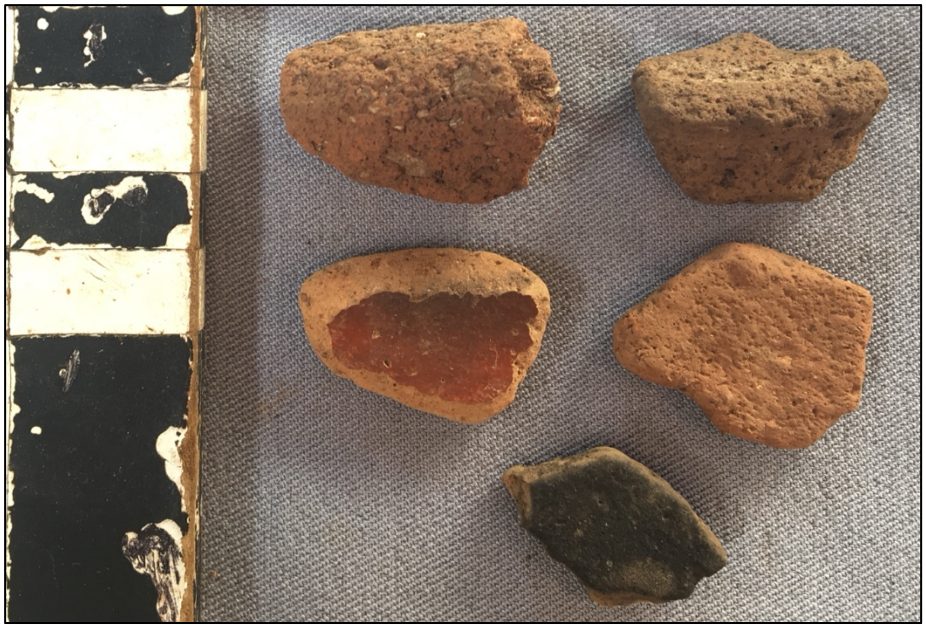
Figure 7.39 Ceramic sherds from test pit 230A, Level 2, Lot 1.

Level 3, Lot 1: 20-40cm. New level to expose bedrock in the remainder of the pit, at NW: -46, NE: -49, SE: -41, SW: -37, C: -39cm from datum. The matrix and land of this level was the same as level 2 (7.5YR 3/4). Vista Alegre Estriado sherds (Figure 7.40) were found in this stratum.

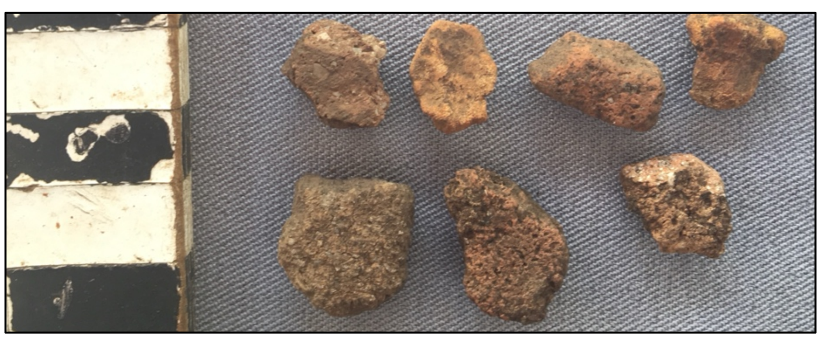
Figure 7.40 Ceramic sherds from test pit 230A, Level 3, Lot 1.

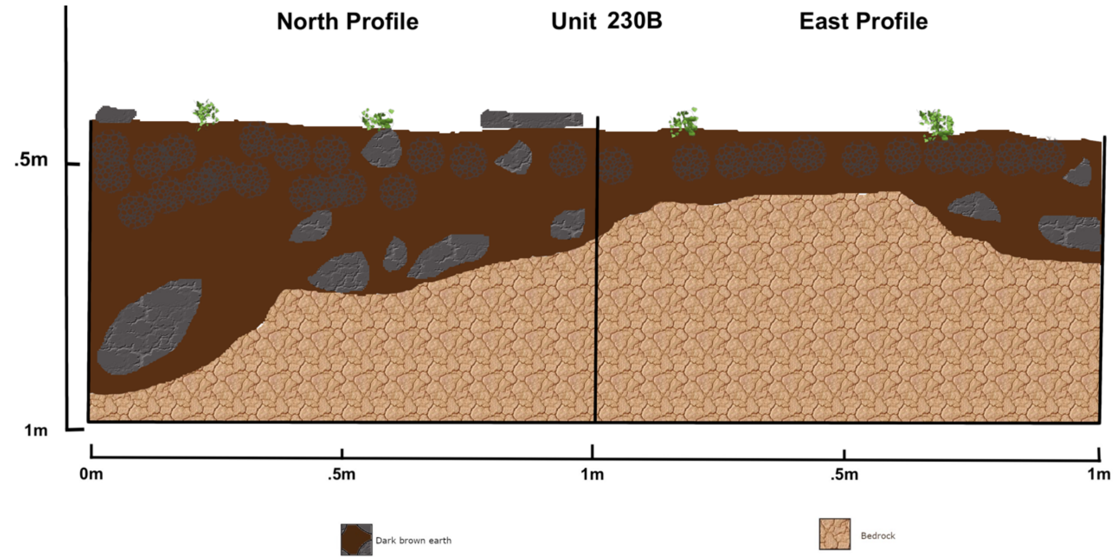

Figure 7.41 Profile of test pit CO230-B-1.

Unit CO230-B-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -10, NE: -11, SE: -13, SW: -12, C: -11cm from datum. No cultural materials were recovered at this level.


Figure 7.42 Ceramic sherds from test pit 230B, Level 2, Lot 1.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -32, NE: -32, SE: -37, SW: -35, C: -32cm from datum. Matrix was composed of very dark brown earth (7.5 YR 2.5/3), with many roots and very small stones, some medium-sized stones like *ch'ich'*, and possible the remains of a rough floor. Ceramic materials were found at this level, mostly Vista Alegre Estriado *tecomate* sherds (Figure 7.42).

Figure 7.43 Ceramic sherds from test pit 230B, Level 3, Lot 1.

Level 3, Lot 1: 20-40cm. New level to expose bedrock, which was NW: -57, NE: -34, SE: -48, SW: -58, C: -51cm from datum. The soil at this level was slightly darker than at level 2, dark brown in color (7.5YR 3/3), and with medium-sized stones - slightly larger than those above. Sparse ceramic material was recorded at this level, only a few sherds of Vista Alegre Estriado (Figure 7.43).

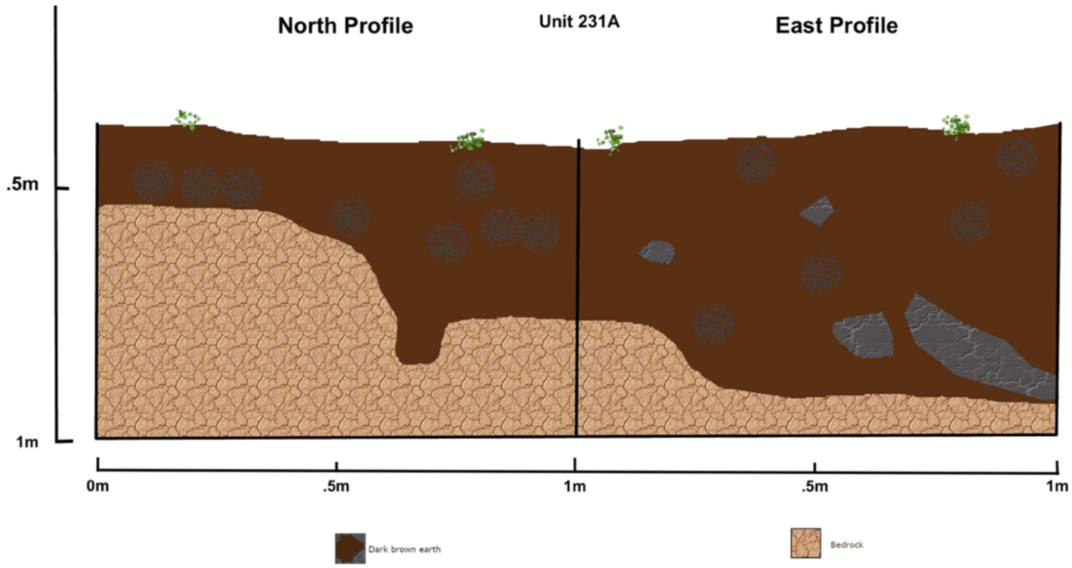

Figure 7.44 Profile of test pit CO231-A-1.

Unit CO231-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -16, NE: -20, SE: 16, SW: -15, C: -12cm from datum. No cultural materials were recovered at this level.

Figure 7.45 Ceramic sherds from test pit 231A, Level 2, Lot 1.

Level 2, Lot 1: 0-20cm. Excavated to NW: -32, NE: -36, SE: -37, SW: -32, C: -32cm from datum. Matrix composed of dark brown earth (7.5YR 3/4) mixed with medium roots and small *ch'ich'* stones. Bedrock was found in the western part of the excavation. Ceramic sherds of Encanto Estriado Sacná (Figure 7.45) were recorded at this level.

Level 3, Lot 1: 20-40cm. New level down to NW: -32, NE: -57, SE: -58, SW: -59, C: -34cm from datum 0. The earth was still dark brown in color (7.5YR 3/4), with roots and small stones, and some medium stones. Bedrock was found further to the west of the excavation, but not to the east. No archaeological materials were recovered at this level.

Level 4, Lot 1: 40-60cm. New level to expose bedrock, which was NW: -32, NE: -60, SE: -74, SW: -59, C: -34cm from datum. The soil was slightly lighter brown than the upper levels (7.5YR 4/4), with medium size stones and small roots. Bedrock was found throughout the pit. Sparse ceramic materials were recorded (small sherds of Encanto Estriado Sacná *ollas*), and the level and excavation of this pit was closed.

7.12 Area 233 (Cenote K'aasja')

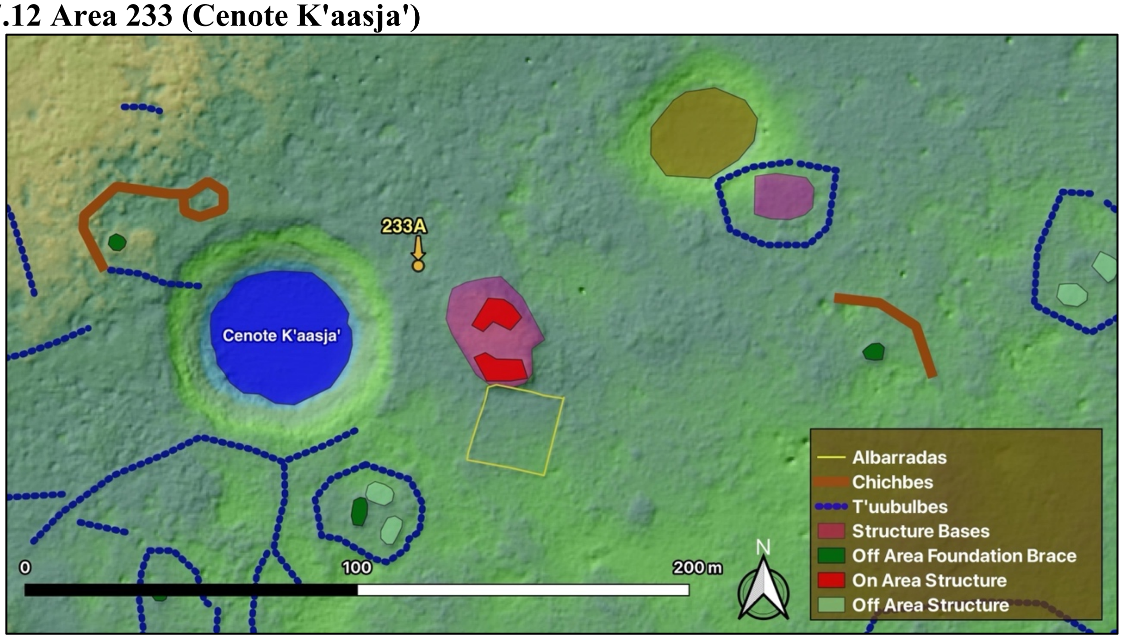

Figure 7.46 DEM map of Cenote K'aasja' and location of test pit 233A.

The 233A test pit was decidedly more remote than most other units we excavated at Cobá, as it was neither close to the city core, nor to a *sakbej* terminus or major *sakbej* in general. There was still a sizeable structure to the east of the cenote we dubbed Cenote K'aasja' (bad water), but besides that one, most other structures in the nearby area were few and small. Today the area is thick jungle, and walls for a large cattle pen remain (though abandoned for decades, at least) to the south of the large structure and north of the *mensura* boundary line between ejidos Cobá and Nuevo Xcan. The water of Cenote K'aasja' was roughly 5m lower than the surrounding land, but its sides sloped down gently rather than the sharp doline walls of other *cenotes*, making the water table easy to access here. That, combined with nearby *ko'op*, intimate an area apposite for agriculture, especially fruit trees like avocado and cacao.

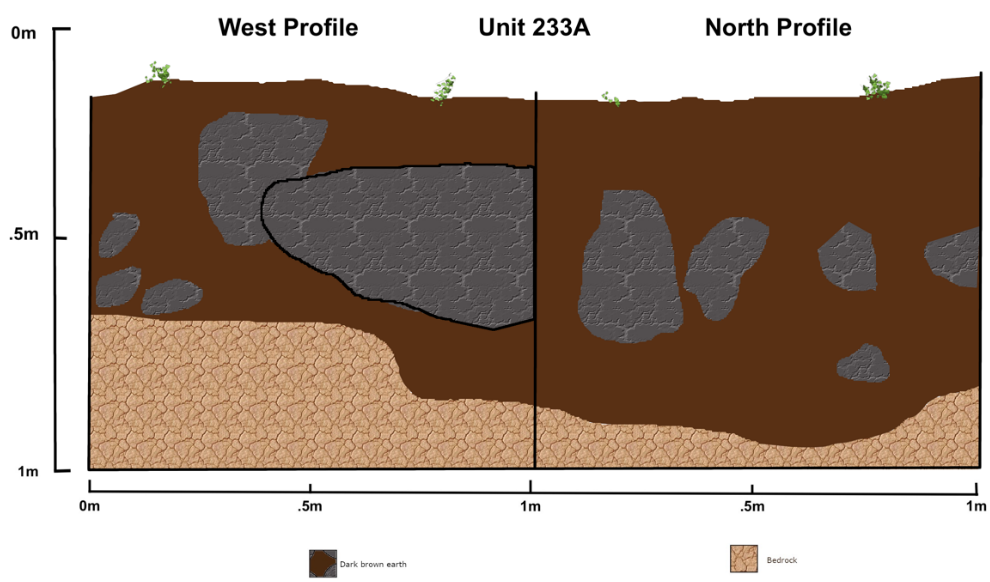

Figure 7.47 Profile of test pit CO233-A-1.

Unit CO233-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Humus. Surface level with initial measurements of NW: -17, NE: -13, SE: -14, SW: -15, C: -10cm from datum. No cultural materials were recovered at this level.

Level 2, Lot 1: 0-20cm. Excavated down to NW: -34, NE: -35, SE: -38, SW: -35, C: -34cm from datum. Matrix was composed of very dark brown earth (7.5 YR 2.5/3), with many stones and small roots, and some medium-sized roots. There were two large stones at the bottom of the level. Ceramic materials were found at this level.

Level 3, Lot 1: 20-40cm. New level after 20cm (but without removing the large stones that remained in the limits of the excavation), it was excavated up to NW: -35, NE: -50, SE: - 52, SW: -55, C: -51cm from datum. The soil was very dark brown (7.5YR 2.5/3), with some small roots and some medium and large stones. Ceramic sherds were recorded at this level, but they were sparse, eroded, and small, so remain unidentified, as in the other levels of this excavation.

Level 4, Lot 1: 40-60cm. New level after 20cm (and then removing a large stone on the east side) which were NW: -36, NE: -68, SE: -72, SW: -69, C: -62cm from level of datum 0. The earth was very dark brown (7.5YR 2.5/3), with small and very large stones. Bedrock was found to the southwest of the pit. Ceramic material was recorded at this level.

Level 5, Lot 1: 60-80cm. New level to expose bedrock to the northeast of the pit, at NW: -36, NE: -87, SE: -72, SW: -69, C: -62cm from datum. The ground was slightly lighter brown than the upper levels (7.5YR 4/3). Very hard stucco on the bedrock. No archaeological materials were recovered at this level.

7.13 Area TZ20 (Cenote Xauil near Yaxuná)

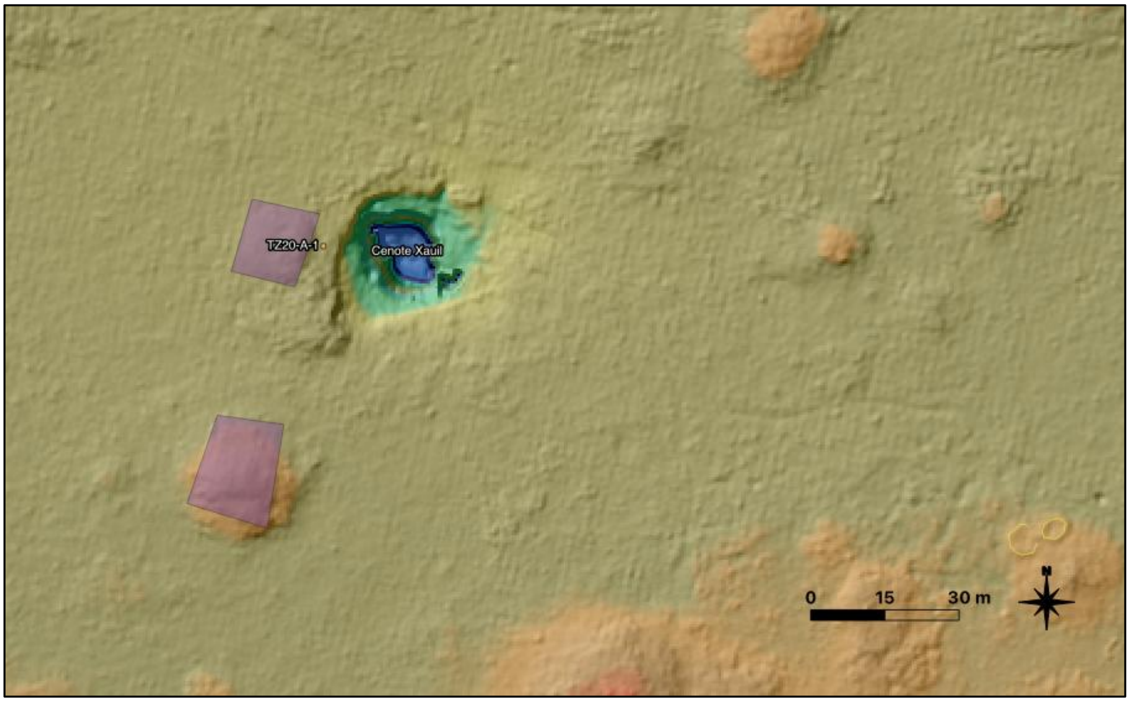

Figure 7.48 DEM map of Cenote Xauil and test pit TZ20A.

Test pit TZ20A was excavated in 2017 near the ridge of Cenote Xauil and a broad structure. Xauil is situated roughly 3.5km east of central Yaxuná, 400m north of Sakbej 1, and 500m ENE from *sakbej* terminus Tzacauil. Ceramic sherds date to the Tsolik occupation at Yaxuná, the eight century AD. The waters of Cenote Xauil are far below the surrounding ground surface, about 17m down. Today local Yaxuneros access the water as it were a well, with a pulley at the edge of the *cenote*, metal bucket, and a long rope. They also practice apiculture here, though the invasive *Apis* species are more common than the native *Melipona* these days.

Unit TZ20-A-1. Dimensions: 1m x 1m.

Level 1, Lot 1: Surface initial measurements of NW: -1, NE: -3, SE: -5, SW: -8, C: -3 cm from datum. No archaeological materials were recovered at this level.

Level 2, Lot 1: Excavated down to NW: -19, NE: -20, SE: -23, SW: -26, C: -21cm from datum. Matrix was composed of very dark brown earth almost black (7.5YR 2.5/2), with small stones, small roots, and some medium-sized roots. Larger stones revealed at the bottom of the level. Few ceramic sherds (Muna Slipped) were found at this level.

Figure 7.49 Ceramic sherds from test pit TZ20A, Level 3, Lot 1.

Level 3, Lot 1: Quickly reached bedrock at NW: -21, NE: -24, SE: -27, SW: -30, C: -28cm from datum. Soil still almost black (7.5YR 2.5/2), with larger stones and some roots. Few ceramic sherds (Muna Slipped, Pisté, and Yokat Estriado) were found at this level.

7.14 Excavation Data Analyses Conclusion

The excavations described above - along with their artifacts and their spatial context amongst important groups at Cobá near water sources - set a foundation for further data analyses in the succeeding chapter and for further discussion after. While much more excavation both at Cobá and at sites along Sakbej 1 will surely provide greater context in future research, these current test pits greatly aid the discussion and meaning of my present research.

Chapter 8 Lidar and Water Data Results and Analyses

8.1 Introduction

This chapter breaks down and details the results of the digitization of features of the lidar DEM data, and water particulate contents from water bodies in the region. After each data set is analyzed, I compare them to one another (including excavation data from the previous chapter) to paint a broader picture of the overall meaning of the data collected at Cobá, Yaxuná, and sites along Sakbej. This provides the background for a more in-depth discussion of the cultural and historical meanings of this data in the proceeding chapter.

8.2 Lidar Digitization Data

This section compiles the results of digitizing features over the lidar DEM maps as polygon and line vector shapefiles, including *ch'ich'* mounds (polygons), water features (polygons) and linear features (lines), which often interact with one another by proximity and direction. Some were ground verified through pedestrian survey, but the vast majority are inferred from the lidar data and with the aid of past mapping like that of Folan and his colleagues (1983). An additional boon comes from the work of Stanton and colleagues (2023), who digitized ancient structures by type at Cobá, which are here used as points of comparison. Based on their point shapefile of 5,968 groups, I calculated Average Nearest Neighbor (ANN) of these houselot groups to a ratio of 0.98 (Observed mean distance: 65.2m; Expected mean distance: 66.6m, Z-Score: -3.25). However, our colleague Scott Hutson (2023) arrived at a slightly different ANN ratio of 1.09 at Cobá by sampling only the area north of the lakes in order to avoid including such large areas of uninhabitable water bodies in the calculations.

This slight difference is important, as a ratio of less than 1 falls on the side of "clustered" while greater than 1 classifies as "dispersed" according to the ANN schema. This value nearing or slightly over 1 posits Cobá amongst other sites where bounded houselots are common, like Chunchucmil and Mayapán. Of the 23 centers studied with ANN by Thompson and her colleagues (2022), only Chunchucmil scored as dispersed, with a 1.09 ratio, while Mayapán was also quite close at a 0.99 index. However, most of the sites in that research were from the Southern Lowlands, while Hutson (2023) found that most sites in the Northern Lowlands he studied with ANN scored above 1, dispersed. This discrepancy could be due to the flatter terrain in the north. In any case, this helps us keep in mind that many of the linear features discussed below were indeed houselot boundary markers that helped shape settlement patterns, even as some also provided additional functions.

8.3 *Ch'ich'* Mounds and Agriculture

Within the Cobá lidar dataset ($104km^2$), I outlined a total of 939 *ch'ich'* mounds with a total area of $14,192m^2$, each averaging $15.1m^2$ (see Table 8.1). Some of the larger *ch'ich'* mounds (15 are larger than $35m^2$, the largest is $45m^2$) were most probably used as platforms for sheds or small houses (Kunen and Hughbanks 2003; Pyburn et al. 1998), as mentioned in Chapter 6, but I believe the vast majority of these were used in arboricultural practices, primarily to support young and/or small trees (Kepecs and Boucher 1996), both physically and to aid in water retention for their roots. Virtually all of these *ch'ich'* mounds are found in and around the grid-pattern area of *sakbej*-walls and *chichbe* discussed below, an area between two very large *áak'alche'* which is somewhat low-lying (roughly 5-7m above the average water table). All of this points to an area prime for arboriculture, and many economically important trees may have grown within this area as fruitfully as those within *ts'aats'* and *rejolladas*. Future research here might examine the chemical components of the soil to determine which (if any) were prominently grown.

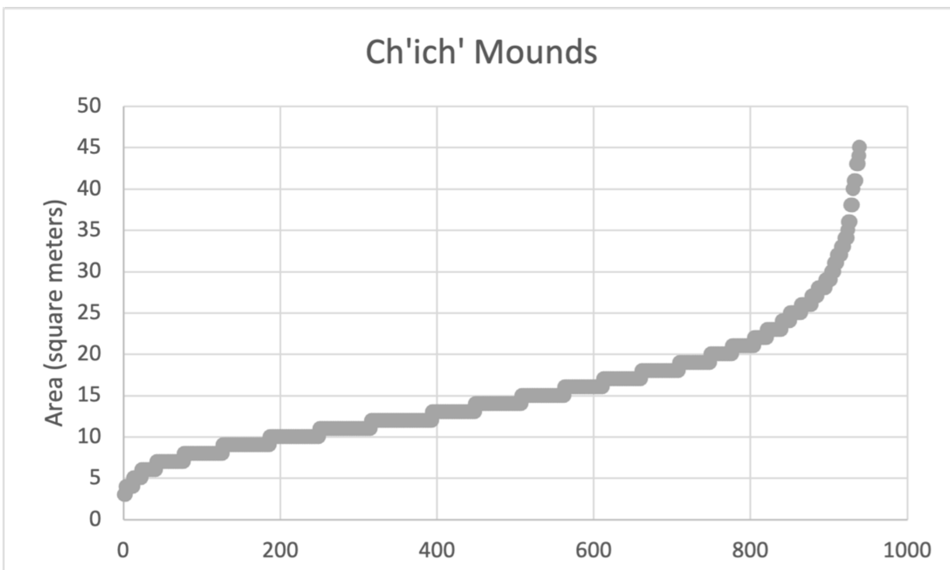

Table 8.1 Scatter plot of area distribution of *ch'ich'* mounds at Cobá. The x-axis represents arbitrary number designations for each mound, so each point along the plot is a single mound.

I also sought to determine how much land at Cobá would have been eligible for *milpa* farming (*meyaj kool*). As detailed in Chapter 6, I accounted for slope, land occupied by structures, and buffers for infield areas. This resulted in 71.75km^2 of eligible *milpa* land, enough to support roughly 40,000 people with average yields of maize, or 70,000 with exceptionally high yields. As the population grew beyond that, Cobá would have depended on foodstuffs from further and further afield being brought into their central markets, something that Sakbej 1 and Sakbej 16 (to Ixil) may have helped facilitate. However, we must also consider that "swidden thesis" originating from Morley (1946:140) is an outdated and inadequate portrayal of ancient Maya agriculture and other subsistence strategies, in reality involving landesque capital and a plethora of crops and wild plants (Fedick et al. 2023), ideas which will be explored further in Chapter 9.

8.4 Water Features and Folan Map Overlays

The Cobá lidar data yielded a total of 84 relatively permanent water bodies which touch the water table (at roughly 7m below average sea level), including lakes, *cenotes*, *áak'alche'*, and the wet parts of *ts'aats'*. Naturally, the water lens is variable geographically, seasonally, and from year to year, but these bodies will retain at least some water through the dry season under typical conditions. These water bodies total 2.55km^2 and average .03km^2, covering roughly 2.5% of the total lidar study area for Cobá. Unfortunately, there is no bathymetry data to go with this model, but *cenotes* are the most likely to hold very deep waters, while *áak'alche'* and the shallower lakes are more likely to recess somewhat in the dry season and in times of drought. Along the Sakbej 1 lidar dataset (134km^2), I outlined 22 permanent water bodies with a total of 0.006km^2, or 5,651m^2, which covers but 0.004% of the Sakbej 1 lidar study area.

Seasonal water features such as small *aguadas*, reservoirs, and catchments were trickier to identify, as they are not simply a range of elevations touching the water table but significantly sloped depressions relative to their surrounding terrain. My experience in the field noting seasonal *aguadas* after heavy rains was helpful to guide these interpretations of the remaining *aguadas* that are not ground verified, as were the maps of

Folan and colleagues (1983). Although these maps (Figure 8.1) contain errors (some *sakbej* changing direction that are straight, orientations of structures off, etc.), they were helpful to mark small features that are difficult to see in the lidar at times, such as small catchments. Flow accumulation models of the lidar were also helpful to find or corroborate such features.

Figure 8.1 DEM of Cobá with overlay of maps by Folan and his colleagues (1983).

I outlined 193 seasonal water features at Cobá, for a total of 0.015km^2 (15,250m^2) with an average of 79m^2, covering only 0.01% of Cobá (see Table 8.2), but it is highly likely that I have underestimated or simply missed many such seasonal water features that remain difficult to identify in the lidar models. No *aguada* at Cobá is further than 20m from a linear feature (discussed below), and most are within but a few meters, giving further credence to the use of some of these linear features to divert water into such drainage areas.

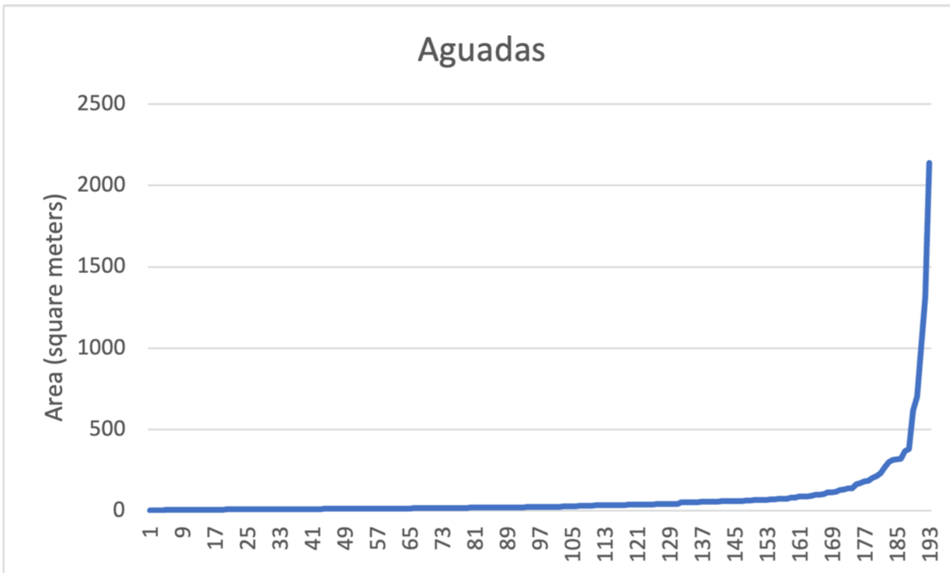

Table 8.2 Line graph of area distribution of *aguadas* at Cobá. Here again the x-axis represents arbitrary number designations for each single *aguada*.

Interestingly, and in contrast to Cobá, seasonal water features totaled similarly to permanent water bodies along Sakbej 1, with a count of 25, yet cover a larger total surface area 0.019km^2 (19,083m^2), which still only amounts to 0.01% of the Sakbej 1 area, akin to the Cobá ratio. This highlights the lack of lakes and higher elevation along Sakbej 1, but we must keep in mind that a) permanent water bodies are deeper and provide more water by volume, and b) there are likely many *cenotes* and wells with restricted openings and caves with water that are not easily identifiable in the lidar data.

There are also a great many small but deep holes in the karst landscape, some of which may even reach the water table. I began to document these during pedestrian survey, and initially attempted to digitize them into the lidar, but I found that their number too great and size too small to incorporate into this research. The majority appear to be so restricted as to make water collection difficult, were it retained in such pits. Nevertheless, in some cases these pits might have been akin to wells and thus an important water source for the neighboring community.

8.5 Linear Features

Within the Cobá dataset I drew a total of 2,720 *chichbe* and 3,833 *t'úubulbej* over the lidar DEM data. The total length of *chichbe* in that area measured 190.7km, while length of *t'úubulbej* was 276.8km. The average elevation above mean sea level for *chichbe* was 3.59m, with a median of 0.26m for the same. *T'úubulbej* averaged 3.93m above sea level, median 1.81m asl. Within the Yaxuná lidar dataset, virtually all linear features are *albarradas* associated with houselots of the modern town of Yaxuná and with their *milpas*, therefore, as elsewhere, I refrained from digitizing lines that were clearly modern. Though they are still culturally Maya, they are not a reflection of the landscape during the times I discuss in this research. There is a small cluster of what appear to be small *chichbe* and perhaps pit kilns amongst structures roughly 2km northwest of the core of the Yaxuná ruins, but the very small sample size and proximity to the edge of the lidar dataset lend them unsuitable for robust analysis. However, their proximity to a small *ts'aats'* is noteworthy. Along the Sakbej 1 dataset I outlined a total of 231 *chichbe* (total length 12.87km; average 55.69m) and 160 *t'úubulbej* (total length 10.36km; average 64.77m), most of which cluster heavily toward east - the Cobá end of the causeway - as we shall see in the heatmaps.

For ease of comparison, the density of linear features combined (not including *sakbej*) at Cobá is 4.45km/km^2, while along Sakbej 1 this figure is only 0.17km/km^2 and would be all the smaller without the bundle towards Oxkindzonot on the outskirts of Cobá. As mentioned, all linear features at Yaxuná other than *sakbej* appear to be associated with contemporary milpas and other modern boundary marking, thus unsuitable to this same analytical treatment. Pooling from a wider dataset, however, the publicly available G-LiHT data from NASA contain 458 tiles (distinct areas of lidar, commonly long thin rectangles in this case) within the Mundo Maya (many in the northern Yucatán, some even transecting Cobá) with an approximate total area of 1,118km^2 that were analyzed by Schroder and his colleagues (2020) for architecture and other features, including "walls," which they use as a catchall term for *albarradas* and any other freestanding additive linear features. They identified 10,287 such walls with a total length of 700.9km (Schroder et al. 2020:3), a density of 0.62km/km^2, while also noting the difficulty of archaeological identification of walls due to modern usage.

Of course, much of that area was either uninhabited or more sparsely inhabited than an urban center like Cobá, but from my own examination of many of these tiles along with other lidar datasets in the region I have concluded that, even at sites with large and/or many structures, the degree of non-*sakbej* linear feature construction is often paltry to none. There are notable exceptions, such as Chunchucmil, Mayapán, some sites in Yalahau, and Xelha, but even these do not have the same level of ubiquity as at Cobá, nor do they appear to have the same character and function. Xelha, for instance, has a dense network of linear features that are quite narrow and for the most part are unassociated with any discernable architecture in the immediate vicinity (Figure 8.2). Such linear features continue along the northeast coast and appear to pertain to Late

Postclassic coastal settlements. Clearly, Cobá has a particularly high ratio of linear features relative to other sites and areas, and a particular strategy and reasoning for constructing them.

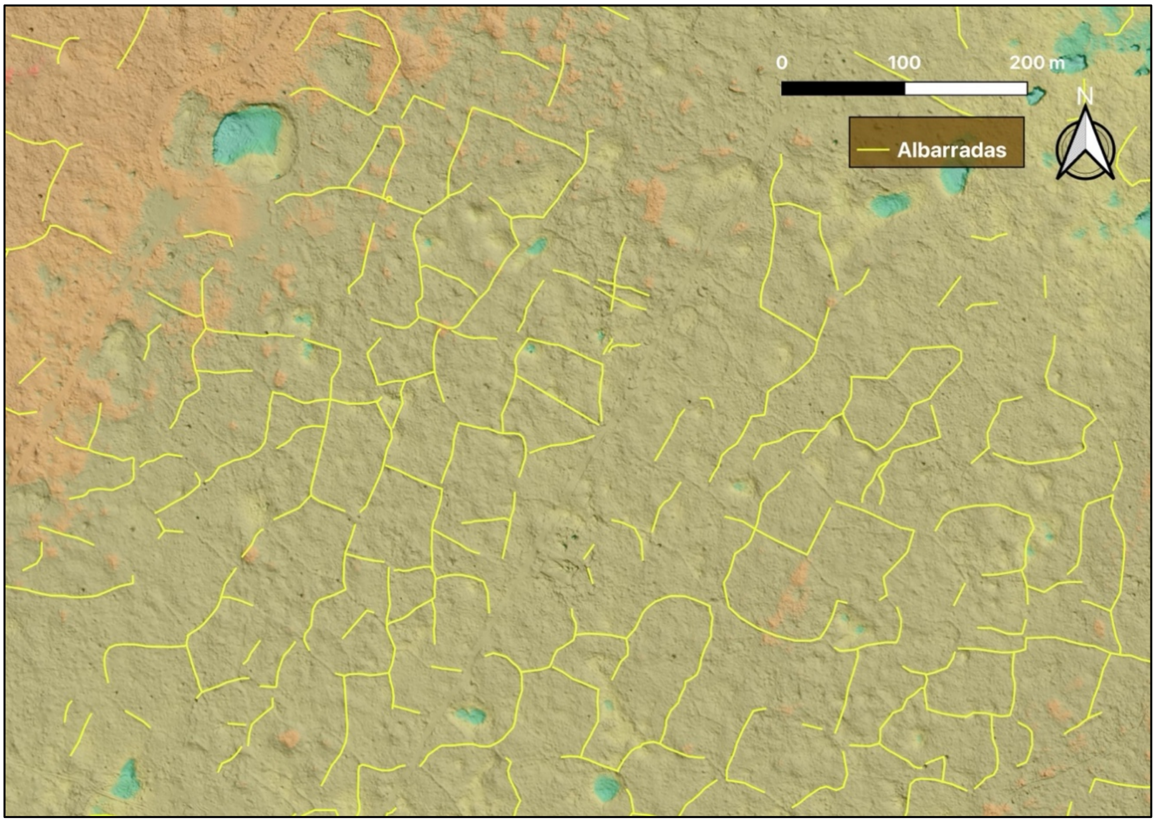

Figure 8.2 Map of Xelha with dense area of *albarradas* northwest of the site core.

8.6 Flow Accumulation

Before moving on to heatmaps, it is necessary to support the argument that these linear features are involved in water routing with lidar data models. Here it is helpful to visit the flow accumulation model imaging of Cobá (Figure 8.3), which computes a hydrologic based model of where and how forcefully water should traverse the landscape, with low values indicating little to no flow, and high values indicating large amounts of flow. We can immediately recognize that *sakbej* are sharply delineated with low values for their relatively flat surfaces, and that along their sides are high values, almost giving an appearance in the model of water flowing along roadside drainages, in some areas pooling into catchment areas.

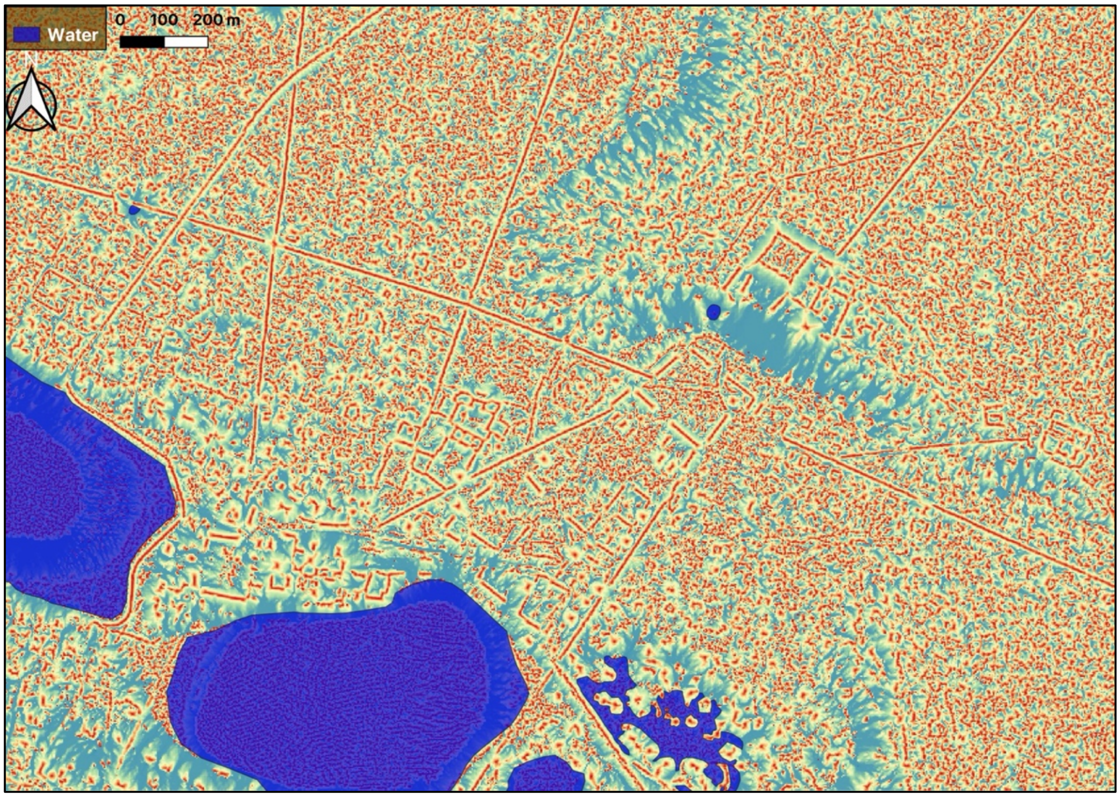

Figure 8.3 Flow accumulation model of lidar data of central Cobá. Red represents areas very unlikely to accumulate rain runoff, light blue represents areas most likely to accumulate runoff, and yellow in between.

In some locations (Figure 8.3), there are breaches of high values at points where the *sakbej* dip to relatively low elevations, where perhaps water might have flown over them and flooded the road. This might be explained a number of ways. First, this is merely a model using arbitrary thresholds within the data models and algorithms, and we could simply tighten these thresholds to eliminate such breaches. We also should consider that the 3m resolution to obtain workable models slightly mutes the sharpness of short rises like these linear features, which may also have an impact. Second, the *sakbej* have eroded and been subjected to other formation processes over the centuries and might have been taller and better maintained when in active use and thus prevented such breaches. Finally, it is possible there were points in the landscape where the ancient Cobanecos actually wanted to allow the water to pass over the road during particularly heavy rains, thus allowing the flow through these breaches on purpose in order to prevent a larger scale flooding of the road at such areas.

Chichbe and *sakbej*-walls are not as large nor as stark in their delineation in the flood accumulation models as are *sakbej*, but many of the larger ones do indeed present as sharp lines of low values with flows of high values along their flanks. Considering the scale and number of these linear features, though, it is best to support this not only visually but with some basic statistical analyses. The initial raw data of the flood accumulation model with which I worked (QGIS SAGA Parallelizable Flow Accumulation) had values ranging from 0 to 12,000, but the vast majority of cells (the smallest unit of map data, in this case 3m x 3m, or $9m^2$) fell between 9 and 2,000, and most of those within 9 to 700. The more intense high-end values clustered in only a few places, the edges of *sakbej* amongst them (e.g., several of the few cells over 10,000 cluster just north of Sakbej 1). Along the routes of *chichbe* marked at 2m intervals, values rarely exceeded 500, averaging 43.21 and with a median of 25.79, indicating that, like *sakbej*, the tops of these *chichbe* walkways were rarely flooded, while heavy streams of rainwater would have run along their sides in many cases. The case for *t'úubulbej* is markedly different. Few *t'úubulbej* are easily made out in the visualization of flow accumulation, and the values of their routes are much higher; over 50 *t'úubulbej* had vertices with values above 500 and a dozen over 1000, averaging 68.24 and a median of 34, demonstrating that *t'úubulbej* were more prone to allowing water runoff to pass between their steppingstones.

Of course, not all *chichbe* were necessarily meant to divert water, nor were all *t'úubulbej* placed where water flowed, otherwise these results would be even more extreme. Some *chichbe* may have merely served as boundary markers and/or walkways connecting houselots or structures without water management as a factor. Likewise, many *t'úubulbej* were likely simple and easy constructions for walkways and stone boundary markers without consideration of flooded areas. Even when they are in swampy or flooded areas, such low-lying spots that are not heavily sloped will not register heavily on flow accumulation models, and thus their corresponding *t'úubulbej* will not contribute to a numerical difference in the above analysis. Even so, the above data combined with field experience and ethnographic comparison demonstrates that a significant amount of these linear features served not only as boundary markers and/or walkways; their sides also functioned as culverts for rainwater. With that in mind, I will analyze the heatmaps under the notion that some (but not all) *chichbe*, *sakbej*, and *sakbej*-walls could and did serve this purpose, while *t'úubulbej* allowed water to flow by.

8.7 Heatmaps

The first point of interest when analyzing the heatmaps of both *chichbe* and *t'úubulbej* (Figures 8.4 and 8.5) is the dearth of these linear features in the core of Cobá. This is explained by two main factors. First, the modern town of Cobá which straddles Lake Cobá precludes most archaeological architecture and linear features. Second, in the extant core including the Cobá Group, Macanxoc Group, and other central groups (much of which is available to the general public via tourism), there exist large open public spaces, including ballcourts and what were likely markets. Therefore, there was not as great a need for delineating private spaces (houselots or otherwise), nor creating berms for agriculture. Furthermore, much of those central complexes rest atop large, raised foundations, so that their plazas were not prone to flooding, thus rendering *t'úubulbej* construction unnecessary. Major foot traffic would have moved atop those plazas and along the network of Cobá *sakbej*, which becomes dense in the center, as many of them meet and cross there. There do exist a few small scattered *chichbe* and *t'úubulbej* within the central region, but by no means dominate the landscape, thus only faintly register on the heatmaps.

In the *chichbe* heatmap (Figure 8.4), we immediately notice several hot spots, most of which coincide, I believe, with agricultural zones. In the far north at the Sakbej 27 terminus (dubbed Xmakaba) is one such area which is low lying and would benefit from *chichbe* to aid in soil accumulation. Likewise, the accumulation of *chichbe* on either side of the middle area of Sakbej 3 (where it is interrupted and branches into Sakbej 26) is also relatively low lying, and contemporary *milperos* of Cobá utilize the area for *kool* (*milpas* or farm plots), growing watermelons, squash, corn, and other crops. The story is the same for hot spots north and south of Sakbej 1 as it progresses towards the city center, and an area southeast of Kitamna. The greatest region of *chichbe* density, however, is an intriguing area west of the crossroads of Sakbej 8 & 14, about 3km south of the city center.

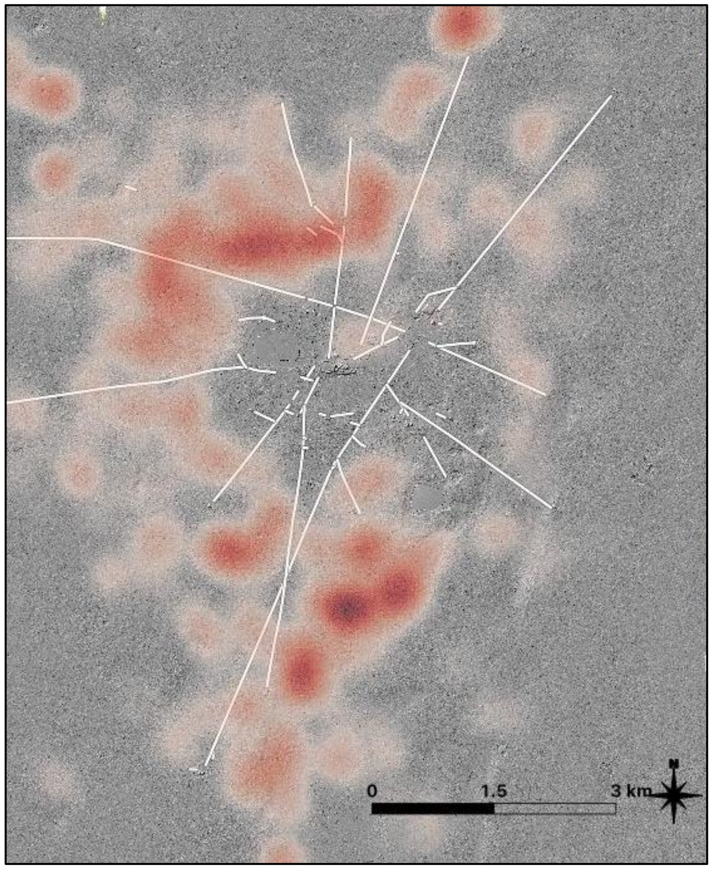

Figure 8.4 Heatmap of *chichbe* density weighted by length at Cobá.

Here a network of *chichbe* and other linear features delineate what I believe to be agricultural plots, acting as one of the main breadbaskets of Cobá. In one area in particular, the lots take on a grid pattern, the linear features forming these grids faced with stones and rising up sharp from the ground, resembling *sakbej* more than *chichbe* in many respects, but still smaller and less regular than typical *sakbej*. We have taken to calling them *sakbej*-walls, as they do not conform to the typical descriptions ascribed to either *chichbe*, *sakbej*, walls, *albarradas*, or any other linear features discussed herein. Beyond the grid area, a surrounding wider region continues with similarly sized (ranging approximately 3,000-5,000m^2) lots, but in the more typical style of winding and sometimes open-ended *chichbe* found elsewhere throughout Cobá. Considering the pattern of architecture, I believe many of these are indeed houselots, but consisting primarily of farmers using much of the land around them to that end, helped by the *chichbe* in their tasks of accumulating soil and retaining water. The grid of *sakbej*-walls and the connections to *chichbe* would also allow for foot traffic in the area. It is also possible that turkeys or other animals (at nearby San Juan de Dios a family was keeping a few *kitam*/peccaries in a pen in 2018, personal observation) were raised and bred in the *sakbej*-wall grid area, a hypothesis which might be confirmed or discarded by future excavations.

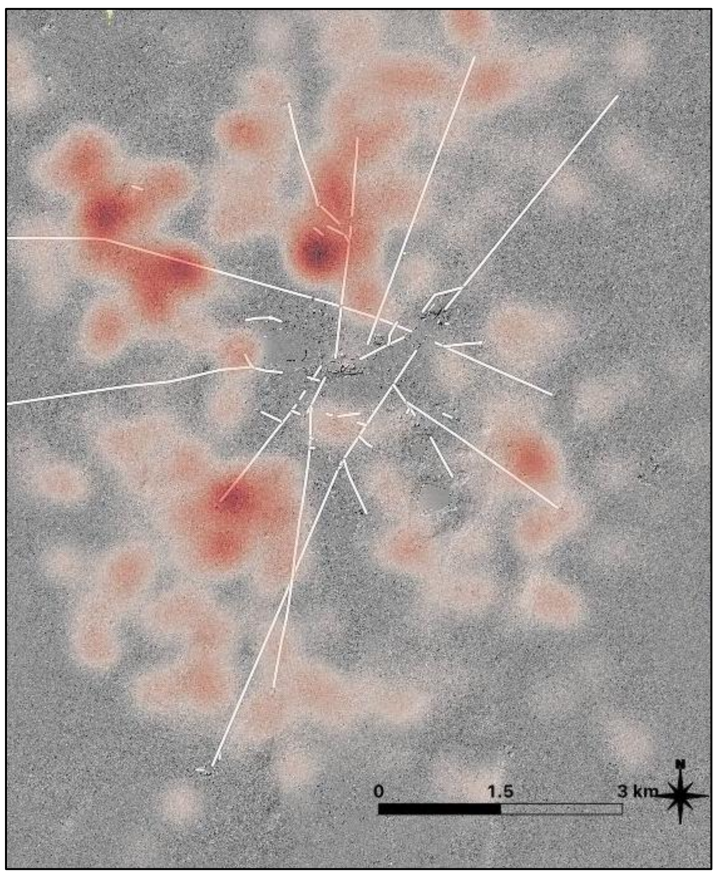

Figure 8.5 Heatmap of *t'úubulbej* density weighted by length at Cobá.

The *t'úubulbej* heatmap (Figure 8.5) shows some overlapping density areas to that of the *chichbe* map, but also a few key dissimilarities. There are a couple of faint hot spots around Xmakaba, but a notable absence of *t'úubulbej* in and around the *sakbej*-wall grid area discussed above. I believe the predominance of *chichbe* and *sakbej*-walls in that region precluded the area from major flooding despite its location in a low-lying area. It was walled off to prevent outside flooding, and the walls were walkable so if there was any internal small-scale flooding from rains, there would still be no need for steppingstones over minor flooded spots with so many *chichbe* and *sakbej*-wall walkways present. Other areas are similar to the *chichbe* map but with important distinctions. The Kitamna hot spot is closer to that terminus rather than southeast of it, and the densest part is around the *sakbej* just before it reaches Kitamna.

The Sakbej 3 fork area likewise clusters its *t'úubulbej* closer to the *sakbej*, and into pockets of very low-lying terrain that is highly prone to flooding. The *t'úubulbej* hot spots north and south of Sakbej 1 sit further west than that of the *chichbe* counterparts, especially in two clumps: one to the south of a permanently wet outlying water body of Lake Cobá that would only connect to it in extreme high-water events, and one to the north that encompasses a large *rejollada*. In general, *t'úubulbej* seem to connect to the *sakbej* with greater frequency than do the *chichbe*.

When we compare these heatmaps to those for various categories of domestic (or at least non-monumental) architecture (Figure 8.6), further patterns emerge. Interestingly, foundation braces on platforms at Cobá have the greatest density just east of the Nojoch Mul group, as do off-mound foundation braces, though this latter category is better represented in other areas, such as north and west of the central area and in the Kitamna region. Platform structures heavily concentrate around the central Cobá lakes, associated with the monumental structures found in the central areas.

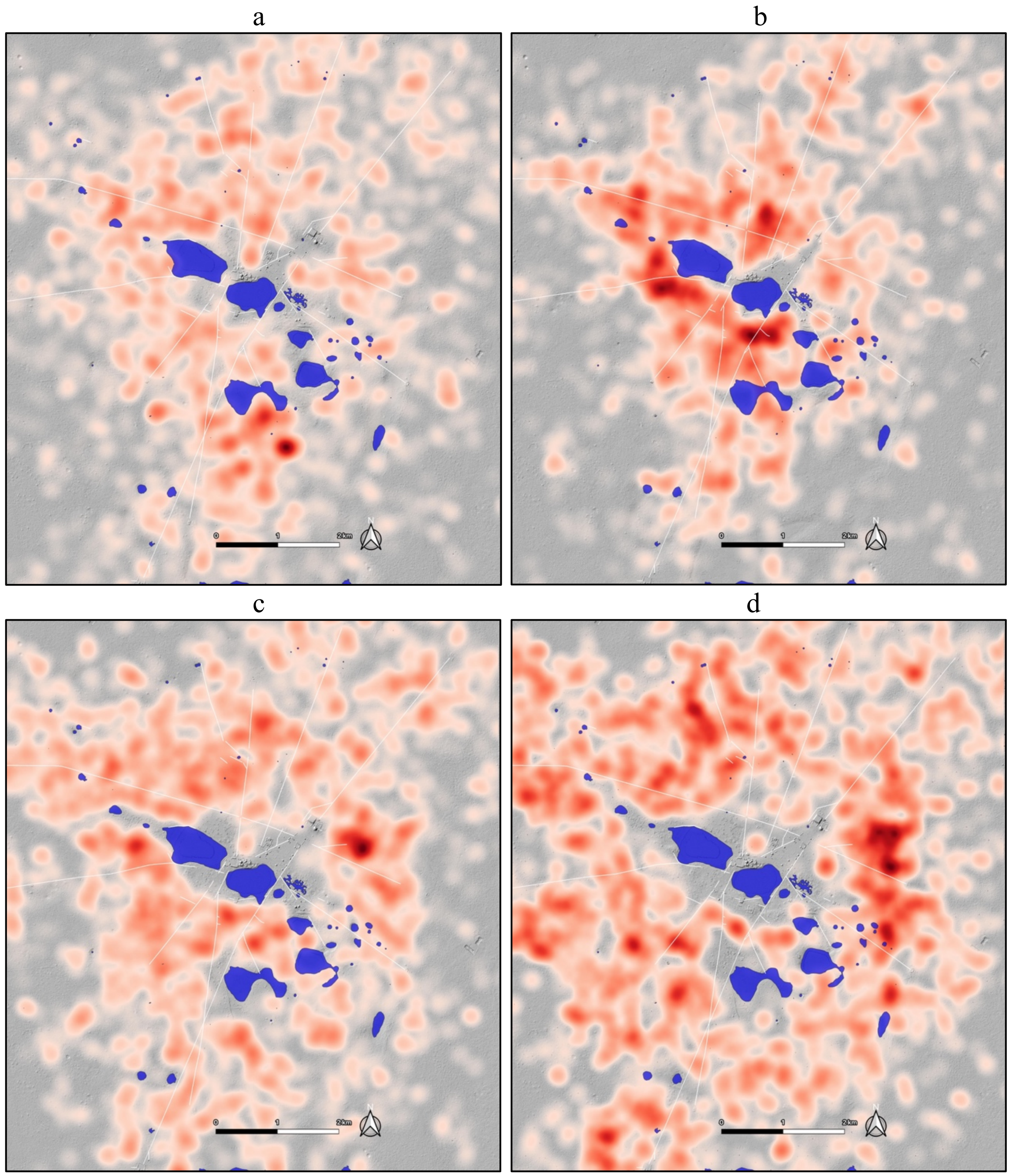

Figure 8.6 Heatmaps of architectural types. a) Off-mound structures; b) Platform structures; c) Platform foundation braces; d) Off-mound foundation braces

Importantly, most *sakbej* termini areas also contain monumental architecture, but appear not to have drawn in as much settlement of platform-dwellers, who were more likely to be of higher status. This might indicate that the monumental structures at sakbej termini were the main residences of the elite in those areas, supported by surrounding commoners rather than a middle class, the latter of which instead clustered toward the lakes and center of town.

The *sakbej*-wall grid area is best represented by a density of off-mound structures, while structures atop platforms pool more densely toward the center of the site around lakes Cobá and Macanxoc. Water management becomes more critical for those living in off-mound structures in low lying areas, as flooding poses a more immediate risk. The off-mound structures of the grid area also support an agriculture-dense hypothesis, as platform building would take up too much valuable land for crops, plus commoners whose primary role as farmers would be unlikely to have the means to construct more elaborate buildings with platforms.

At Ceren, earthen houses with *bajareque* walls (Kievit 1994) were surrounded by kitchen gardens and other agriculture (Lamb and Heindel 2011; Lentz et al. 1996; Zier 1980). Mere foundation braces might not suffice for all buildings in the cases of storage sheds, for example, to preserve foods in an area where *chultun* are at constant risk of flooding from below. Though further ground verification survey and excavation work remain, it appears that the majority of the structures in the grid area are not particularly elaborate architecture and do not display a great deal of variation. This, combined with the boundary walls forming the grid pattern, fits the description of Lohse's (2004) micro-community pattern clusters, which are associated with a higher incidence of productive agricultural sectors.

The *ch'ich'* mound heatmap of Cobá (Figure 8.7) further substantiates the idea of the grid area as an agricultural area, specifically arboriculture. The vast majority of *ch'ich'* mounds were found in and around this area, with other clusters somewhat further away to the south near Lake Nochakan and a small cluster to the northeast on the other side of Sakbej 30 near its termini but also in a low-lying swampy area near a smaller *áakalche'*. The clusters of *ch'ich'* mounds within the grid area are often situated near corners of intersecting *sakbej*-walls or *chichbe*, but occasionally they are found further afield from such linear features.

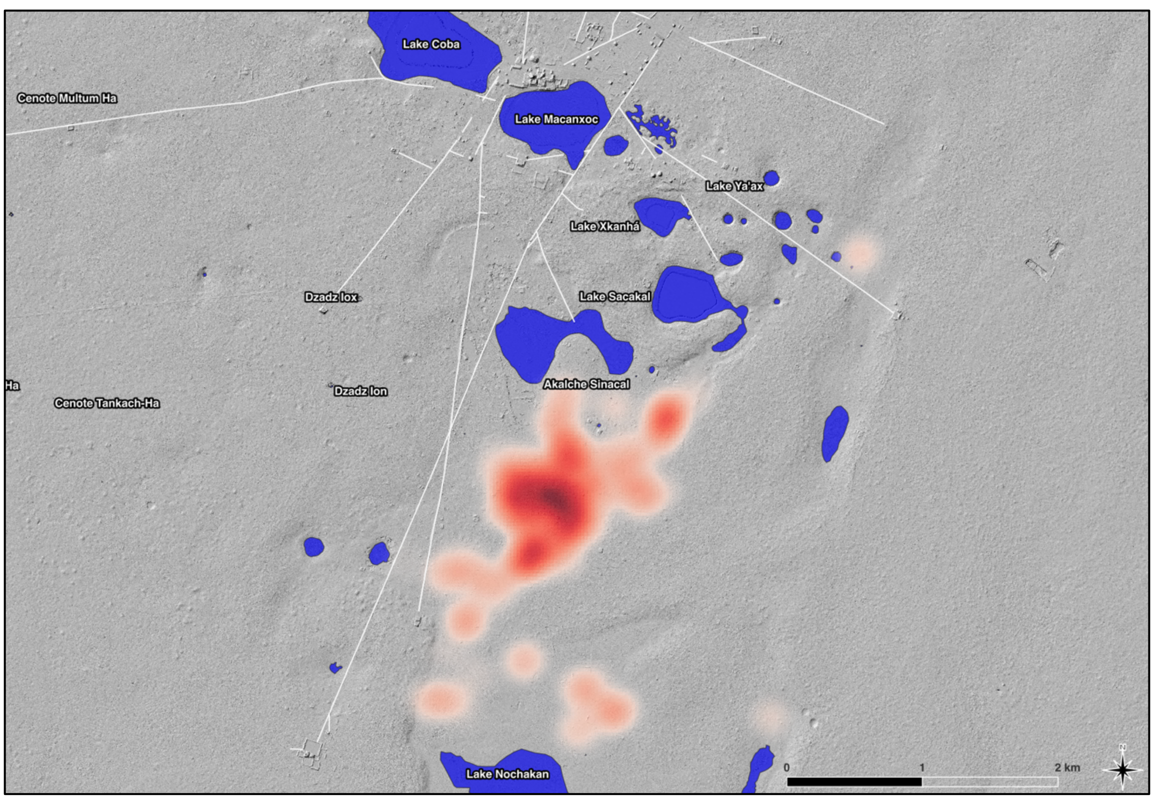

Figure 8.7 Heatmap of *ch'ich'* mound density at Cobá.

Moving on to Sakbej 1, these heatmaps and any maps in general that depict the whole of the almost 100km *sakbej* can be difficult to image for easy viewing in many formats due to its long narrow length. To accommodate for this, and to better analyze the smaller communities along Sakbej 1, we will visit each community of note one by one after looking at the larger distributions. That said, we begin with a heatmap of *chichbe* along Sakbej 1 (Figure 8.8).

Figure 8.8 Heatmap of *chichbe* along Sakbej 1.

The greatest density of *chichbe* sits near Cobá, around a site known as Oxkindzonot. A similar scenario exists for the *t'úubulbej* Sakbej 1 heatmap (Figure 8.9), but even more pronounced. Oxkindzonot is heavily aligned along Sakbej 1 and in many ways appears to serve as a sort of gateway in and out of the city of Cobá, though it does not block to road as do other structures within the Cobá causeway system. Oxkindzonot is only slightly further (roughly 6km) from central Cobá than is the Kukikan terminus (~5.5km, the furthest out of the Cobá intrasite termini), so in fact it might be better understood as the westernmost branch of Cobá city instead of its own distinct "site." Therefore, it is understandable that the concentration of these linear features would resemble that of other communities within Cobá.

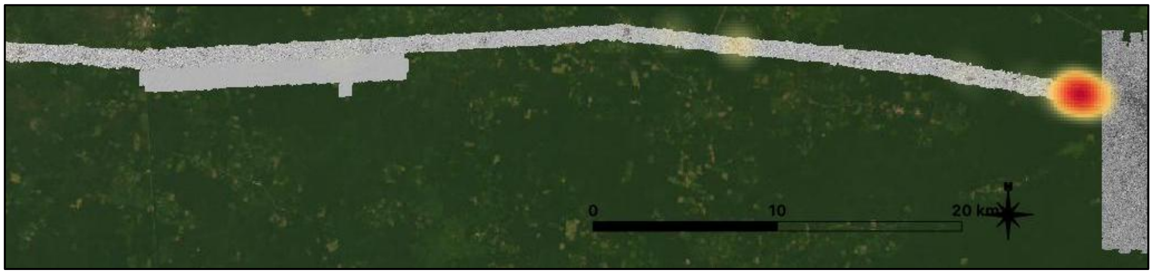

Figure 8.9 Heatmap of *t'úubulbej* along Sakbej 1.

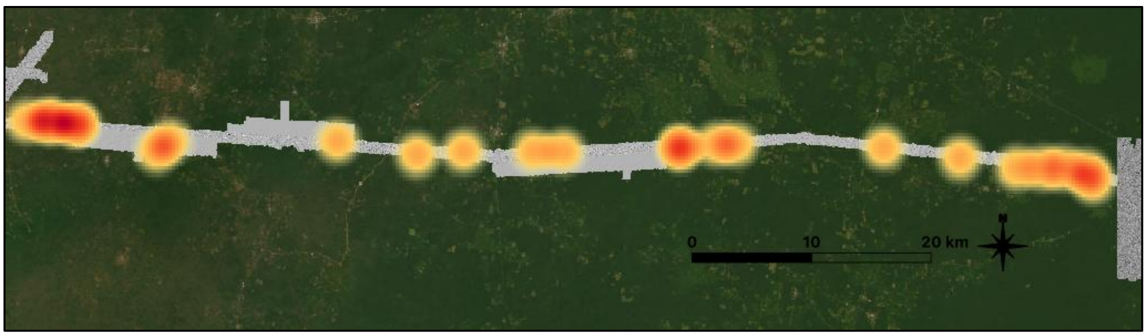

Figure 8.10 Heatmap of water bodies along Sakbej 1 by number of water features.

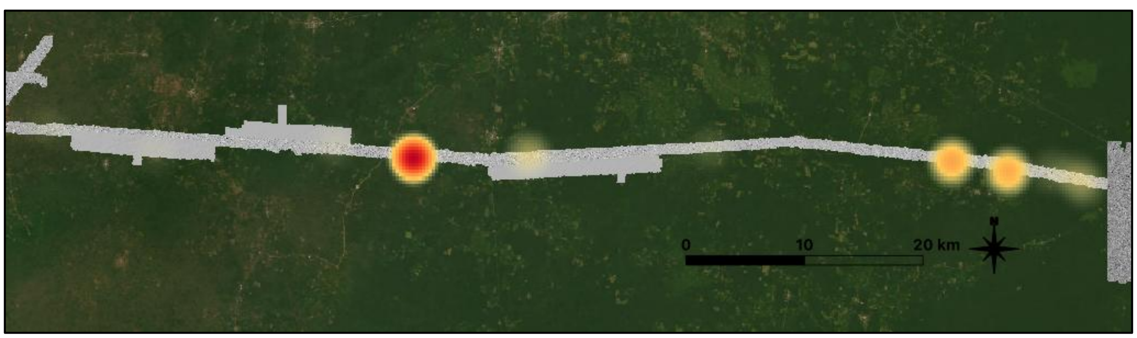

Figure 8.11 Heatmap of water bodies along Sakbej 1 weighted by visible/detectable surface area.

Water bodies (almost certainly all *cenotes* and *ts'aats'*) along Sakbej 1 do not cluster in the same fashion, as seen in the heatmaps for water by number of features (Figure 8.10) and weighted by area (Figure 8.11), that latter of which heavily skews toward Ekal, which boasts a very large *cenote*. Clearly, there is a deviation amongst most of these sites from typical Cobá architecture and community building. To get a closer look at each of these other communities, I begin at the western terminus of Sakbej 1 (i.e., Yaxuná) and move back west towards Oxkindzonot and Cobá.

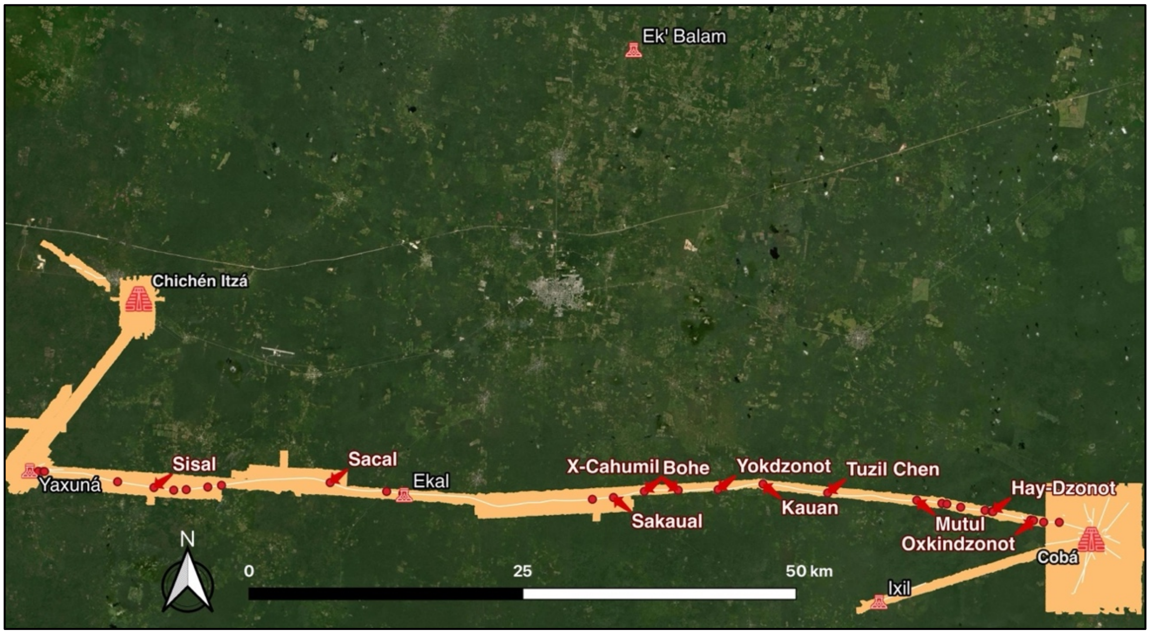

Figure 8.12 Sites along Sakbej 1 encountered by Villa Rojas (1934) and discussed below.

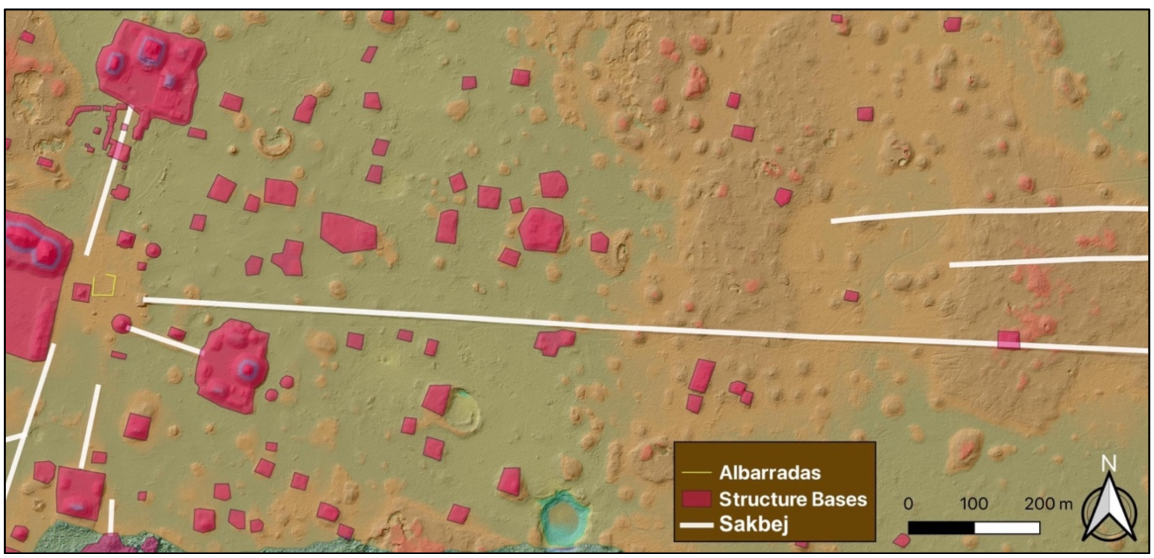

Figure 8.13 Yaxuná and its *sakbej* and structure bases.

8.8 Sakbej 1 Sites

I start in the east in part to follow the path of Alfonso Villa Rojas' (1934) expedition of 1933, still one of the few if not the only non-Maya (though with the aid of twelve Maya of Chan Kom) to have traversed the entirety of Sakbej 1. Immediately Rojas (1934:197) notes the deterioration of the wide area of *sakbej* near this western Yaxuná terminus structure and opines that even then it was largely due to the repurposing of *sakbej* sections as *milpas*. I would add that some of the stones of the *albarradas* scattered amongst the Yaxuná ruins to demarcate other milpas also might have originated as *sakbej* liners. If the *sakbej* stones were being used toward this end, there was likely little in the way of linear features other than *sakbej* in Precolonial Yaxuná, as they would be the move obvious target for the robbing of material to build similar linear features. We also note that unlike Oxkindzonot and other areas close to Cobá, there is very little architecture aligned with or otherwise heavily associated with Sakbej 1 near to Yaxuná. One of the few exceptions is a small structure (right/east end of Figure 8.13) that eclipses the *sakbej* roughly 1300m east of the starting ramp.

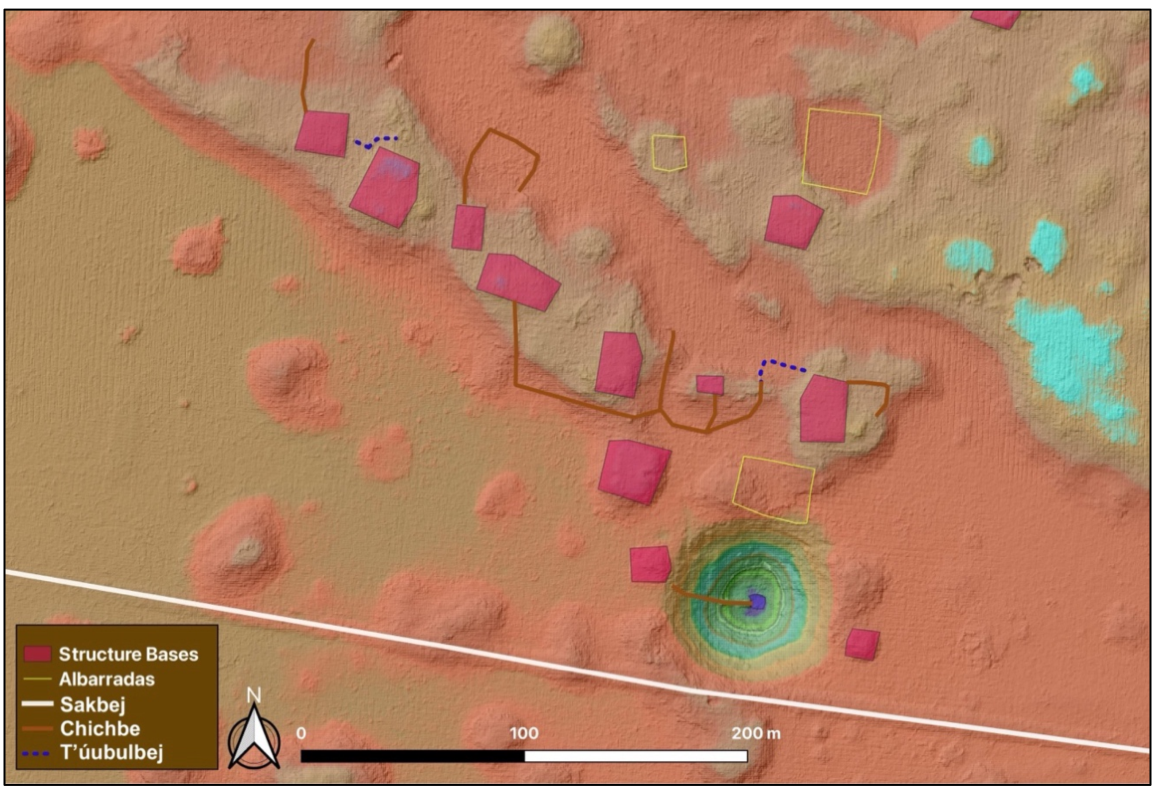

Figure 8.14 Sisal.

Roughly 12km east of Yaxuná is the settlement of Sisal (Figure 8.14). Here we find a mixture of ancient structures and linear features (mostly *chichbe* but also a few *t'úubulbej*) and more recent *albarradas*. The modern (and/or historic) *albarradas* are usually more rectilinear, and rarely articulate with ancient structures, although they do sometimes take advantage of them to complete an enclosure they more often cut through and over old mounds, as the soil is often better on and around them. By contrast, the *chichbe* and *t'úubulbej* often articulate with each other, structures, and/or water features like the *ts'aats'* (and/or *ch'e'en*) seen here at Sisal.

Figure 8.15 *Chichbe* or *sakbej*-like walkway leading to well at the bottom of a *ts'aats'* at Sisal (from Villa Rojas 1934 Plate 3).

When Villa Rojas passed through Sisal almost a century ago, he noted three Maya families living there whom he reports built the *chichbe* leading down into the well at the base of the *ts'aats'* (Figure 8.15), a construction "humble compared with that of the great road ... nevertheless a noteworthy effort as well as a knowledge of engineering, as curious as it is rudimentary, among the present-day Maya" (Villa Rojas 1934:198). It is unclear whether Villa Rojas assumed that the construction was recent or if they told him that it indeed was, but it seems possible that this *chichbe* existed in earlier epochs and was being maintained and upkept at the time in order to access the well. In any case, Villa Rojas appears unaware of what we now call *chichbe* and other such non-*sakbej* walkways in the archaeological record, which is hardly surprising considering that we only know of them in great abundance at a handful of sites.

One further curiosity of Sisal is the fact that the sinkhole is so close to Sakbej 1 that it appears to have either expanded since the construction of the great *sakbej*, and/or the *sakbej* was built so close to its edge that parts of it have since fallen into the depression. The possibility of the former brings up an important point. First, the sudden expansion or formation of a sinkhole has cultural and cosmological significance, as it brings to mind the open maw of Kawak or Witz (a deified mountain and/or cave "Earth Monster," see Stuart 2007), the great centipede maw which acted as a portal to the watery underworld (Taube 2003b).

Secondly, it reminds us of the dynamic nature of the karst landscape, and that formation processes such as the roots of great trees tumbling down old walls are not the only things changing the landscape. Once bountiful *cenotes* that the Maya of a millennia or more ago enjoyed may now be filled in with debris to the point of them being *ts'aats'* or *rejolladas*, and some new *cenotes* may have formed from sinkholes opening in more recent centuries that was flat land in ages past. It is crucial to understand this dynamism in order to avoid assumptions of the modern landscape mirroring that of the ancient, when in many cases it does not.

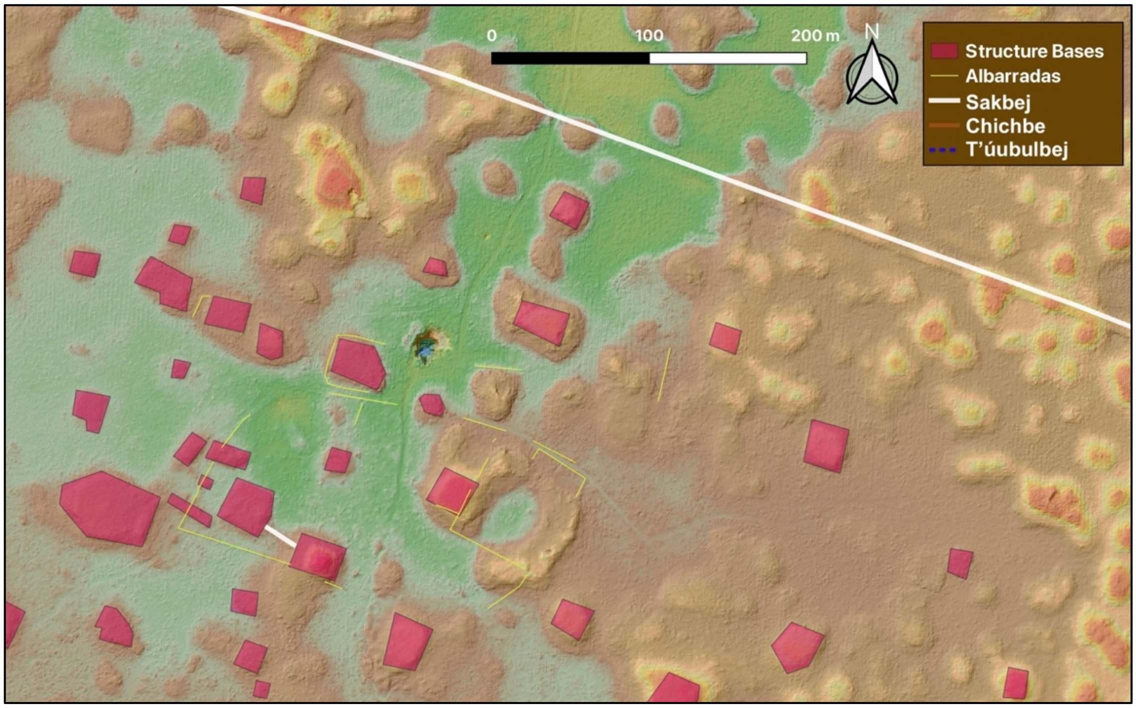

Figure 8.16 Sacal.

Further along Sakbej 1, 28km east of the Yaxuná ramp, rests the small settlement of Sacal (Figure 8.16). There is an opening to a *cenote* roughly 140m south of Sakbej 1, and a cluster of ancient structures around it, mostly further south. The only linear features appear to be relatively recent *albarradas* (perhaps contemporary with the dirt road cut toward the *cenote*) with the exception of a small *sakbej* leading from the front of the tallest (~5m) structure in the area to a nearby platform some ten meters away.

Ekal (Figure 8.17) is by far the largest settlement along the western half of Sakbej 1 (other than Yaxuná), its largest structure looming over a section of the former *sakbej*. I say former because this section of the old road has been repurposed to the extent that it is stripped down to its foundations with hardly a trace for about half of a kilometer at Ekal. The imposing structure in its place rises almost 10m above the platform that replaces the *sakbej*, which itself is almost 5m above the general terrain. Another large group to the south resembles a slightly smaller version of the proposed marketplace areas of central Cobá, with an open plaza with ranged structures to the north, south, and west, a pyramid to the east, and a small structure in the center.

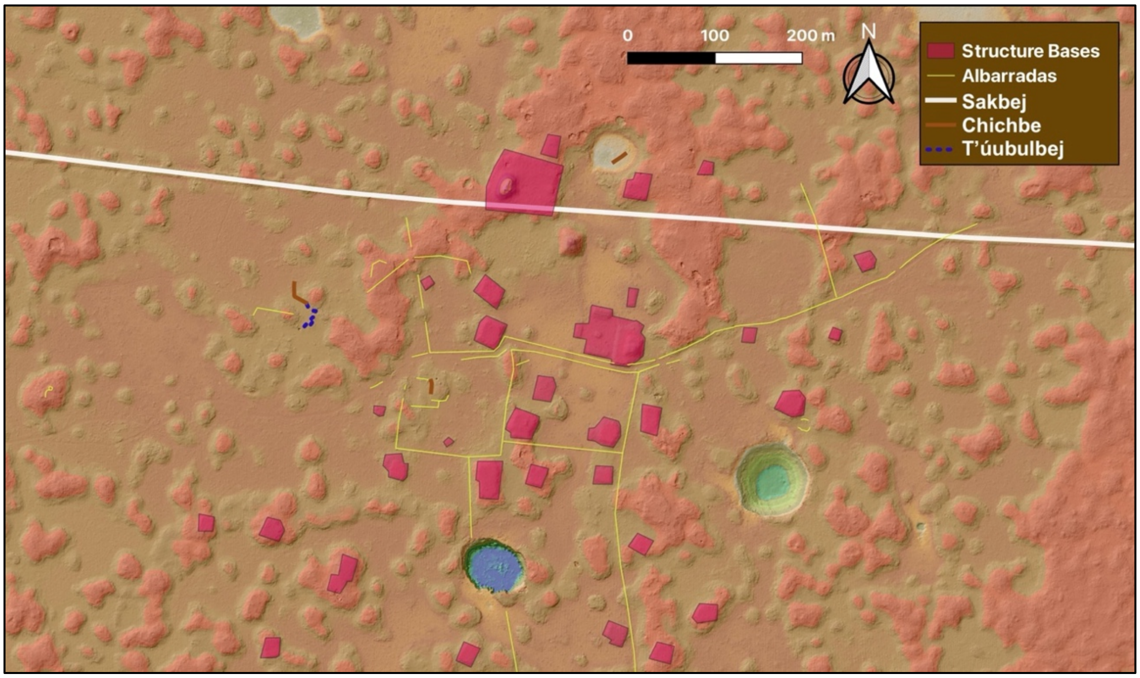

Figure 8.17 Ekal.

Ekal also boasts the largest cenote (in terms of a visible and accessible opening) along Sakbej 1, along with several large rejolladas. Here again, most of the linear features are certainly recent albarradas, some marking the edges of the dirt road used to access the site, which is privately owned by a *ranchero*, which explains the additional albarradas not along the road. However, I believe I have made out a few faint traces of a *t'úubulbej* and a few *chichbe*, one in a shallow *rejollada*.

Figure 8.18 Sacaual.

Past the halfway point, at 55km from Yaxuná, Sakbej 1 goes another small stretch (~240m) sans most of its stones, which were reorganized into the hacienda at Sacaual (Figure 8.18) that rests partially in the path of the old causeway. Perhaps due to the relative antiquity of the hacienda, the *albarradas* here are not quite as rectilinear as other clearly modern lines, and, in some cases, it is difficult to discern if parts of them may indeed be associated with the more ancient structures that dot the landscape. In any case, this locale, though small, benefited through multiple eras from the small well that is now situated just south of the hacienda.

Figure 8.19 Bohe.

The same scenario plays out about another 3km down the road, at hacienda Bohe. Here there are a greater number and density of ancient structures than at Sacaual (Sacaual contains only 12 small structures dispersed over roughly .38km^2, while Bohe boasts 34 structures over a slightly more compact .33km^2 area, a density over three times higher). This is perhaps due to the larger opening of Bohe's two-eyed *cenote*-well than that of the similar but smaller and likely shallower double well of Sacaual. At Bohe, again there are mostly *albarradas* associated with the hacienda, with only a few small traces of *chichbe* and *t'úubulbej* articulating with the more ancient ruins instead.

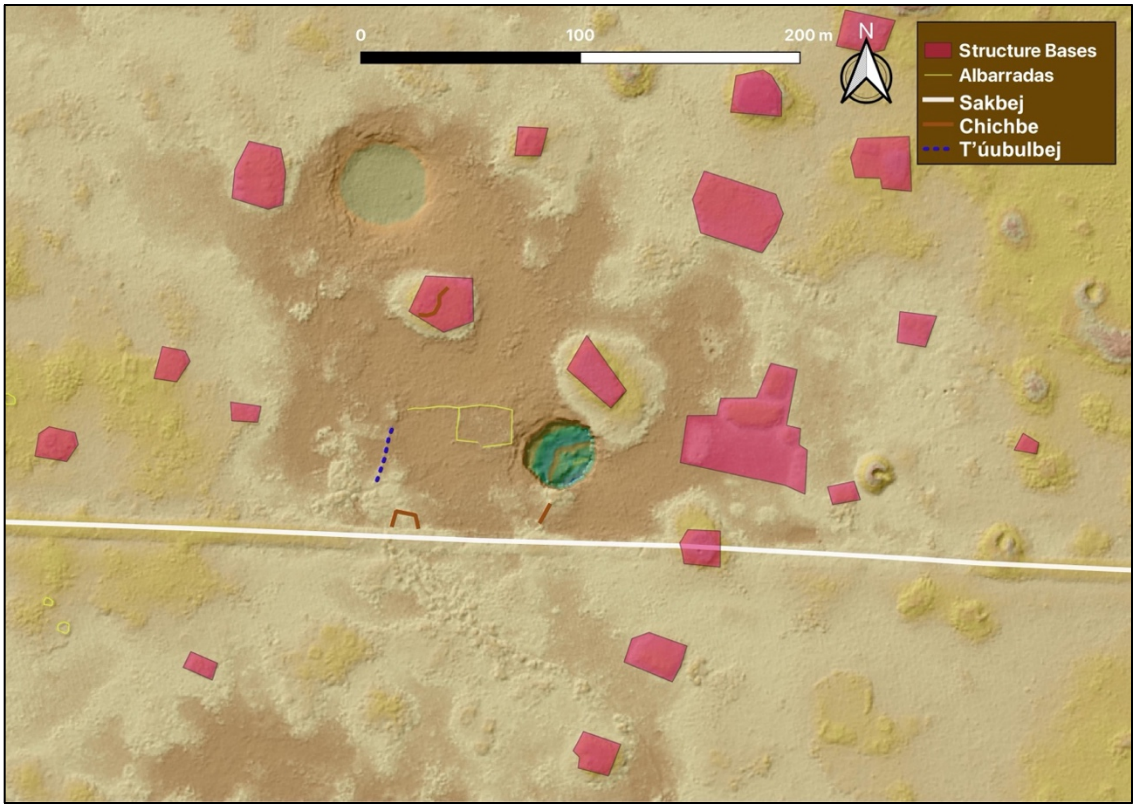

Figure 8.20 X-Cahumil.

At 61km from Yaxuná, the site of X-Cahumil features a large karst opening that appears to be a *ts'aats'*, with its southeastern edge reaching the water table and perhaps going further underground that way into a cave opening. Some Sakbej 1 stones area again robbed for materials here, but no hacienda are other late structure exists here, instead sporting a number of early structures including a plaza group just east of the *ts'aats'*. Several lines of stone are visible west and south of the *ts'aats'*, including a short *chichbe* connecting it to the *sakbej*. I would not be surprised if we eventually uncover occupation dating after the fall of Cobá at X-Cahumil.

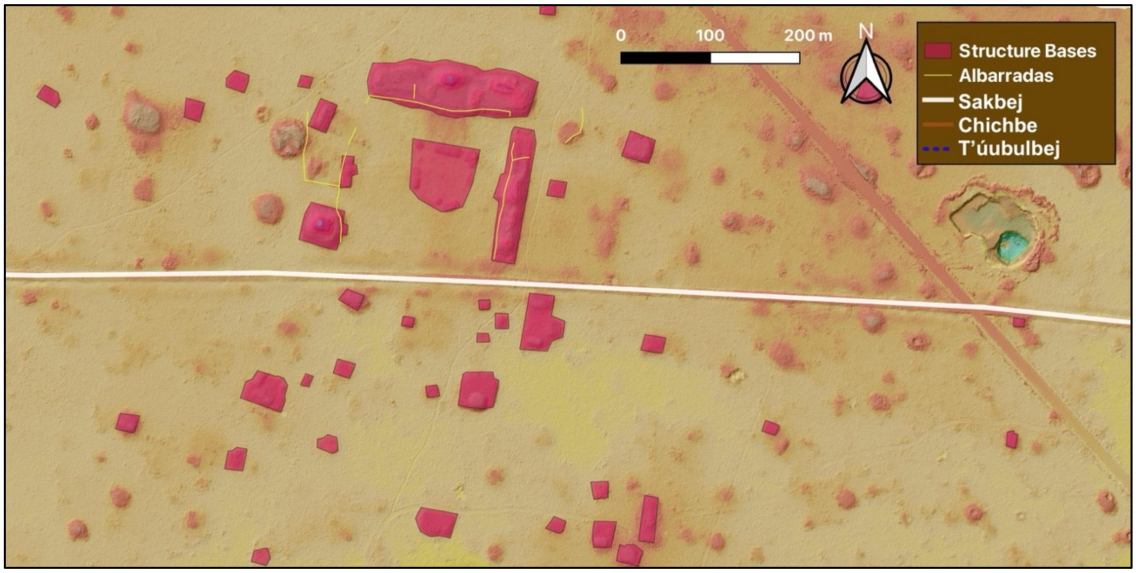

Figure 8.21 Kauan.

Traveling roughly 69km from Yaxuná, Kauan stands out for several reasons. It vaunts the largest architecture along Sakbej 1 since Ekal, with two structures reaching over 10m above the surrounding terrain, one of which is the central structure of a large platform group about 190m wide and 60m deep and facing the *sakbej*. A ranged structure on the east side of this plaza group approximately 140m long running perpendicular to Sakbej 1 and nearly reaching it at its southern edge at first suggests that this is an E-group vaguely reminiscent of that of Yaxuná. However, the tallest structure on the western end of the plaza is positioned too far south to properly align with the ranged eastern structure in order to view equinoxes and solstices. This plaza group is aligned and oriented toward Sakbej 1, a tendency that other structures increasingly share as we progress further toward Cobá. Also noteworthy is the lack of a *cenote* or other water source in the immediate area around Kauan. About half a kilometer east of the main Kauan group lies a "*banco de materiales*," surely for road construction considering its proximity to the modern road, but even if part of this depression was more ancient, it still does not reach the water table. The nearby village of Dzibil has a fresh cool *cenote* at its center, but that is a full kilometer to the southwest. The eponymous modern village of Kauan is only a quarter of a kilometer to the northeast, and may have a *cenote* or *ch'e'en*, but it lies just beyond the reach of our collected lidar data, so this will need to be investigated at a later date.

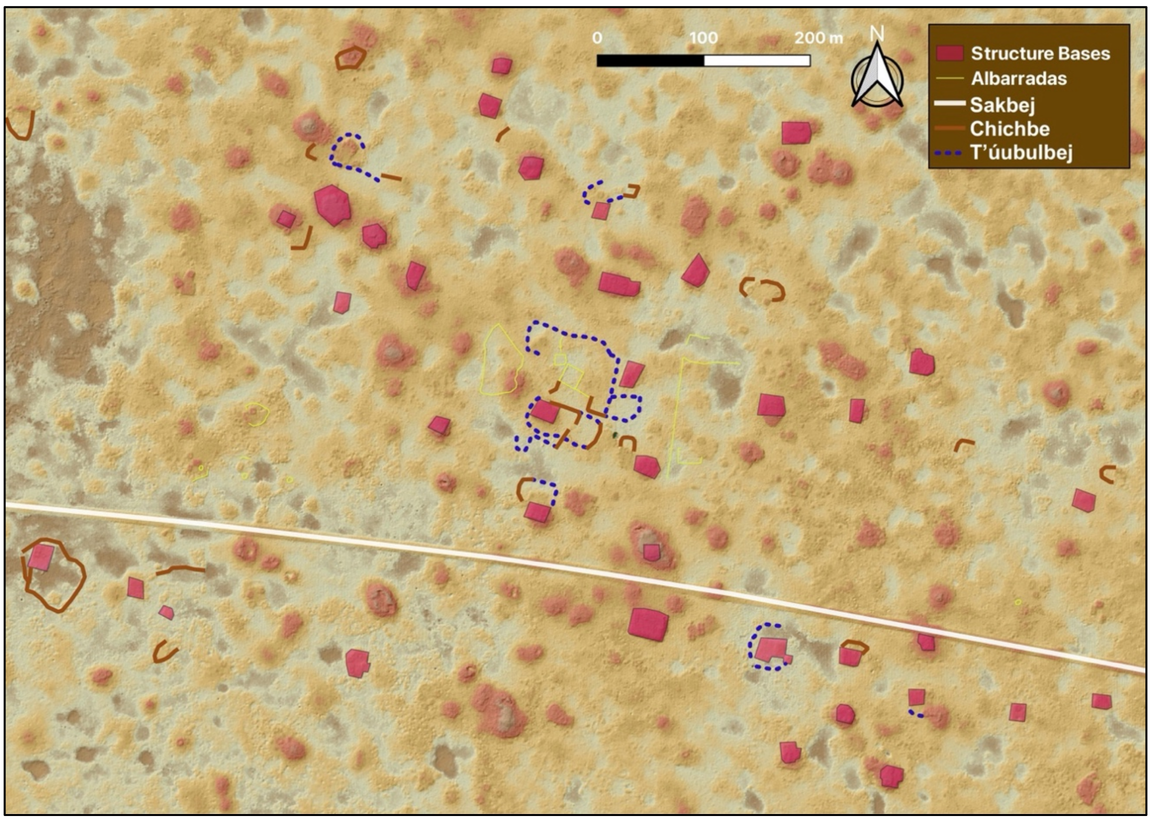

Figure 8.22 Tuzil Chen.

Some 75km from Yaxuná rests Tuzil Chen, where we return to a more scattered layout, although one medium sized structure south of Sakbej 1 does face it. We also start to see more in the way of *chichbe* and *t'úubulbej* despite the small size of this settlement. There appears to be a small *cenote* 125m north of Sakbej 1, with a cluster of linear features and structures nearby. There is also an abundance of circular structures at Tuzil

Chen, some of which may be structure foundations, but many of which are likely pit kilns for lime plaster production. As there is no monumental architecture nearby, this lime must have been used to maintain the *sakbej*, although it might also have been utilized at Kauan or even carted back to Cobá.

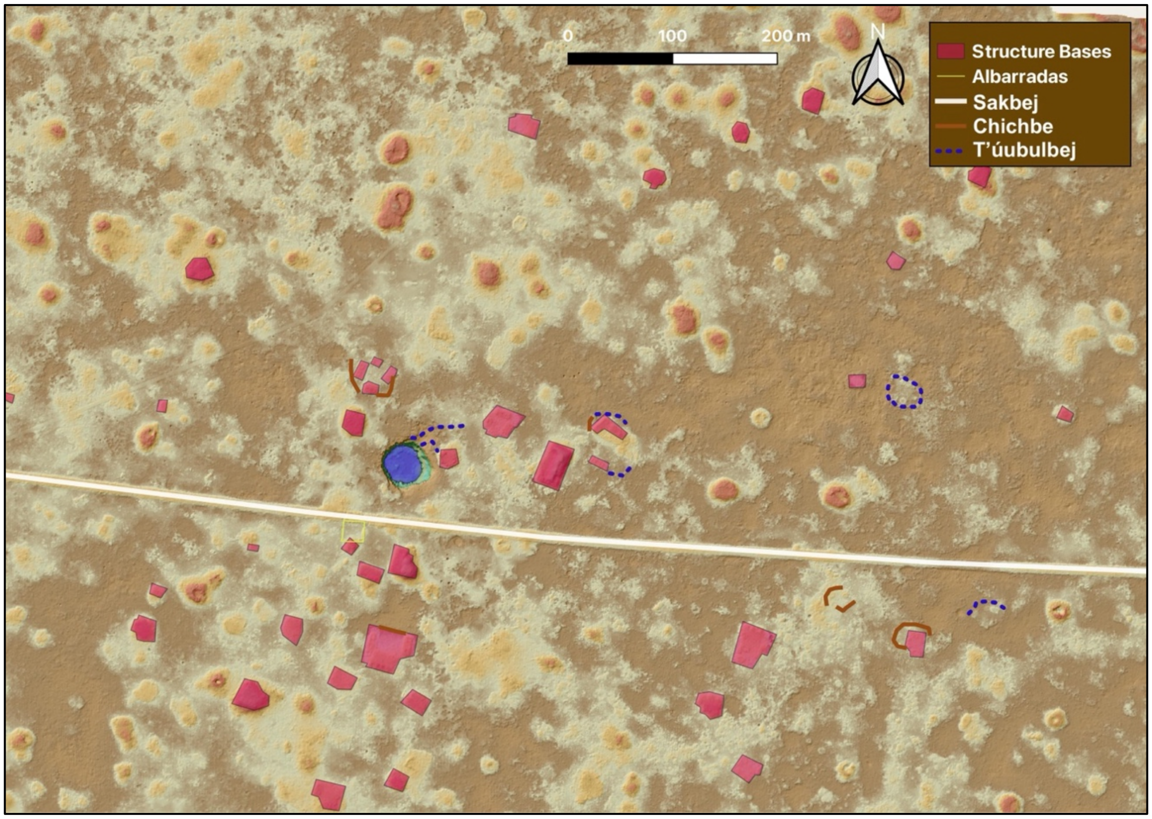

Figure 8.23 Santa Maria.

Another 6.5km down the road, before reaching Mutul, is a site that is omitted by Villa Rojas; perhaps he and his companions did not stop as there were no inhabitants at the time. Today it is near a small community called Santa Maria, and satellite imaging reveals what may be a ranch and farmland in the area just north of the *cenote*. Said *cenote* has an opening ~35m in diameter starting just 25m north of Sakbej 1. There is a structure that appears to have vaulted rooms 100m east of the *cenote* and 40m north of the *sakbej*.

While not abundant, there are several *chichbe* and *t'úubulbej* associated with several structures, especially close to the *cenote*, with two *t'úubulbej* leading from it to different structures.

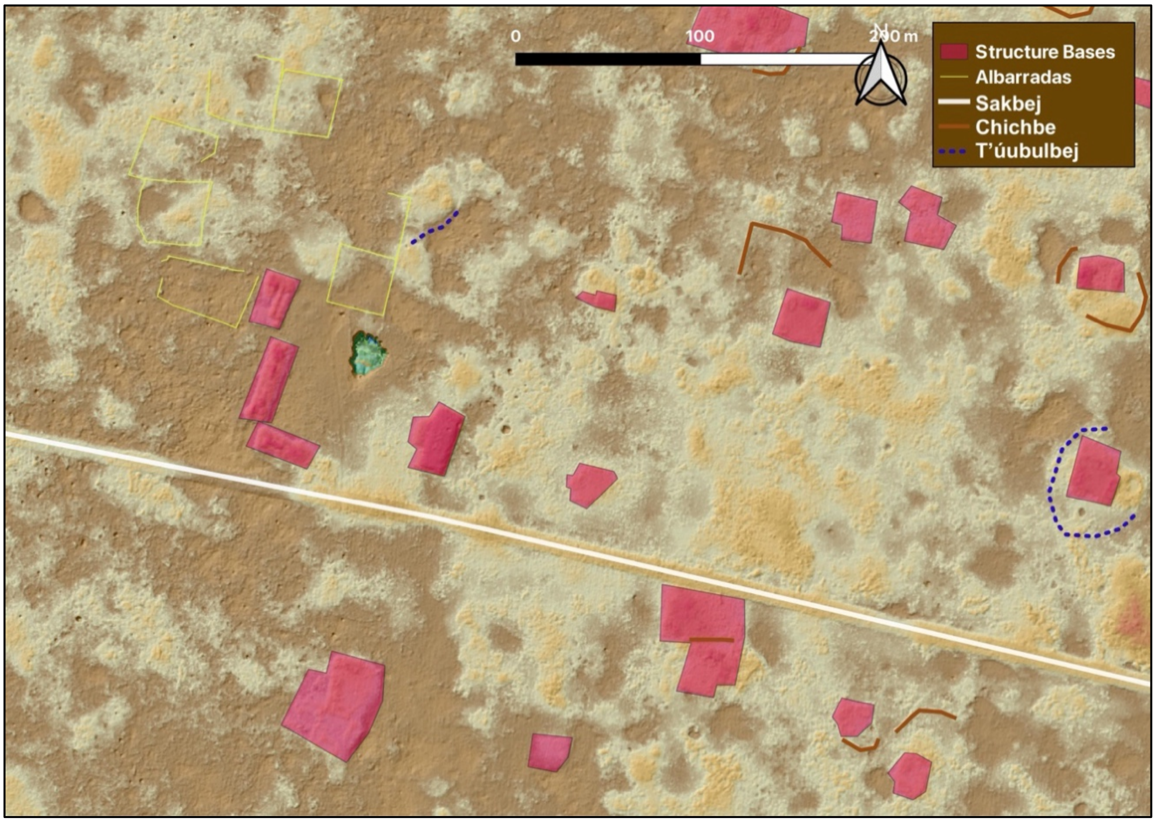

Figure 8.24 Hay-Dzonot.

Closer to Cobá, now over 90km from Yaxuná, the site of Hay-Dzonot shows clear alignment with Sakbej 1, its main plaza structures running parallel and perpendicular to it. In the center of this plaza is a large *cenote* or *ts'aats'*. Villa Rojas (1934:200) notes a stairway build down into this cavity, and the lidar is reminiscent of the ruined stairways leading down to the *ts'aats'* in Kitamna and Ion in Cobá. Again, *chichbe* and *t'úubulbej* are scattered here, but not in great concentration.

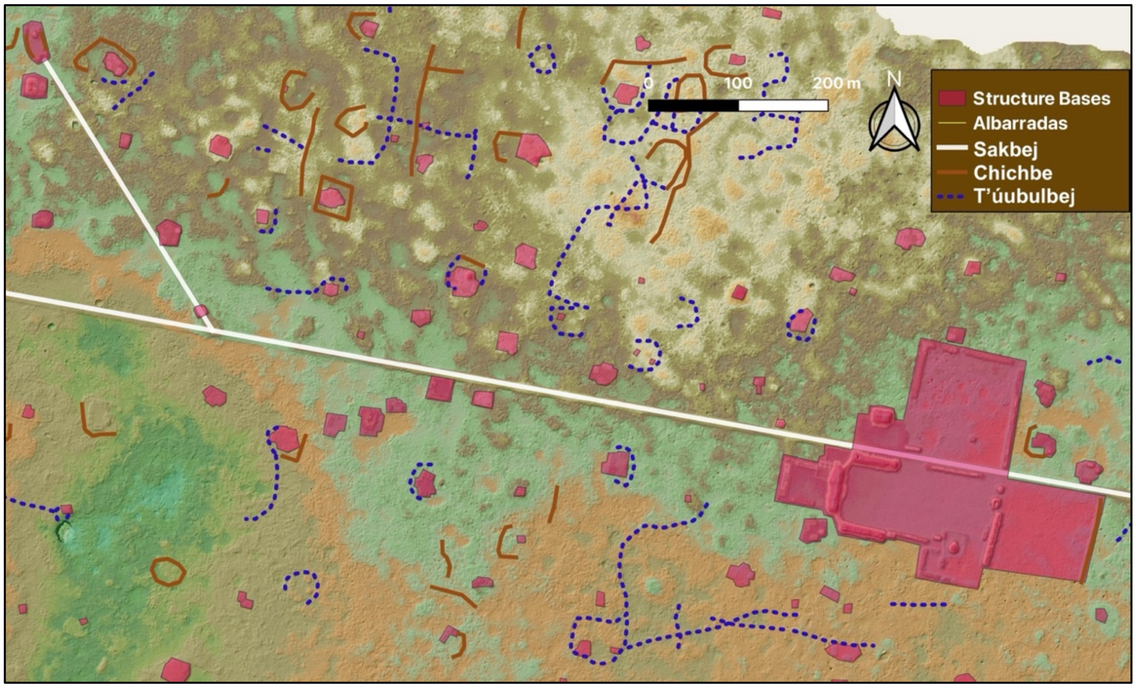

Figure 8.25 Oxkindzonot.

Back at Oxkindzonot, large plazas with ranged structures on either side of Sakbej 1 are in clear alignment with it. These groups along with the many *t'úubulbej* and *chichbe* is much more reminiscent of Cobá than many of the other sites along Sakbej 1, and nearby offshoot road is a hint of the inter-*sakbej* system of the big city. A *ts'aats'* 200m south of Sakbej 1 and less than a kilometer west of the main groups is the only clear water source, but I suspect there may be smaller wells or *cenote* openings in the area.

Seen as a whole, a picture emerges where *t'úubulbej* and *chichbe* are often houselot boundaries, usually walkways, but also often serve as water management features in a complex system that is a Cobaneco phenomenon. This is not to say that such lines of stone are unique to Cobá, as we have already established, they are reminiscent of linear features at Chunchucmil and several other sites. However, their particular arrangement and usage does seem tailored for the particular landscape of Cobá, with its lakes and large low-lying areas that were and are easily flooded in the rainy season. Such flooding would have been even more sudden and pronounced during major hurricanes (or multiple minor hurricanes in succession), which correspond with the rainy season, target the northeast coast of the Yucatán along the Caribbean Sea, and were at least as frequent and strong in the Classic as they have been in recent decades (Brown et al. 2014; Sullivan et al. 2022).

It is difficult to say, therefore, whether this network of linear features result from state-level city planning and directives, or a more organic response to environmental challenges that caught on with the populace. Further research at sites along Sakbej 1 will help us to get a sense of the chronology of when these settlements were founded, occupied, and eventually abandoned. I discuss these ideas more in the next chapter, but for now we turn to the issue of water quality and content in the varied water bodies in and around Cobá.

8.9 Water Quality Data

I tested a total of six water sources: two lakes in and near Cobá, three *cenotes* (two of Cobá, one elsewhere in Yucatán), and tap water at the city of Mérida, Yucatán for control purposes. Table 8.3 shows the attributes of each source, revealing a marked difference in the chemical makeup of the water of various sources at Cobá. Good quality water for drinking (or bathing or cooking) will test as follows: at least some register of dissolved oxygen over 0 (higher values indicate good support for fish and other aquatic life too), less than 10 JTU of turbidity is ideal but under 50 is acceptable, a pH between

6.5-8.5, between .6 and 8 meq/L total alkalinity, 6 to 17 °fH total hardness, and ideally low to no registerable levels of nitrites, nitrates, or harmful bacteria.

Cenote Tamcach Ha is a particular outlier to the norm in several categories, with 0ppm dissolved oxygen (likely slightly higher, but undetectable with equipment used), lower turbidity, and higher alkalinity and total hardness relative to the other bodies of water. This may be explained by the fact that it is a *cenote* accessed down into a cave, without other openings to allow air to circulate, keeping it colder and lowering its dissolved oxygen levels. At 348ppm total hardness, the water of Tamcach Ha would not be wise to drink as one's sole source of water over long spans of time.

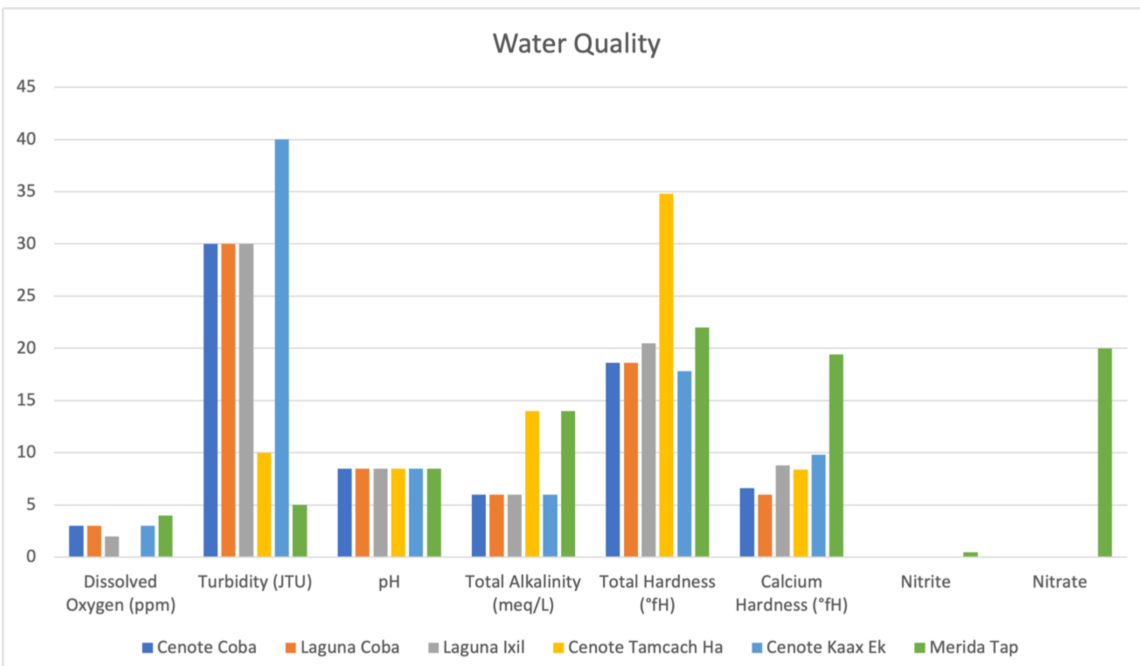

Table 8.3 Water quality of various metrics at a variety of water bodies and sources.

Of note, all of the water bodies were happily free of nitrite and nitrate (again, traces may be present, but were undetectable by the equipment used), while the Mérida tap water contained .5ppm nitrite and 20ppm nitrate, the latter of which is twice the maximum contaminant level suggested by the EPA, which is worrisome for the people of Mérida. The worry for the people of Cobá, however, is the positive coliform bacteria result of the water of Laguna Cobá, understandable considering the close proximity of the town to that lake along with animals and the lack of water treatment there. Of course, this does not directly speak to the coliform bacteria levels of the ancient past of Laguna Cobá, but if today's town of less than 2,000 *ejiditarios* results in the contaminant, Cobá in the Classic Period with roughly 60,000 to 90,000 people (Stanton et al. 2024) would surely have needed methods of filtration and/or the maintenance of the hydrological system through the strategic placement of wetland barriers and the promotion of helpful allies like water lilies and other natural decontaminants.

8.10 Comparative Analysis

As mentioned in the methodology chapter, the arbitrary selection of test pits renders a spatial distribution of ceramic types and other artifacts across Cobá based on said units ineffectual for statistical or spatial analyses. However, it is still interesting to note the overlap between areas with deep cave *cenotes* and/or *ts'aats'* and the kinds of artifacts found there versus the overlap between areas with *cenotes* or other water bodies with easily accessible water close to the land surface and the types of artifacts found in those locales. The *ts'aats'* near Kitamna, for instance, contained a fragment of a ceramic monkey figurine. A troop of spider monkeys at Punta Laguna often congregates at the entrance to a cave with water at its base, and spider monkeys were closely associated with cacao in Maya cosmology. It is likely cacao was grown within Dzadz Iox near Kitamna in the distant past, as it was as recently as the 1970's and early 2000's (Folan

1983; Folan et al. 2009; Terry et al. 2022). The units near Kitamna are also the closest to Cenote Tamcach Ha, with its deep (*taam*) cold water in a dark cave that would make a grand ritual setting but an impractical spot for quotidian water collection. Such sources of water, more difficult to access and away from daily activities and foot traffic, would have made excellent candidates for sacred fonts of *sujuy ja* for ritual purposes.

By contrast, the test pits near surface water showed little to no signs of elite goods or ritual activity. Still, they were often near important complexes due to their prime waterside locations, but in some cases these complexes appear to serve functional production purposes - either agriculture, lime production, craft workshops, or all of the above.

The temporal aspect of the occupation of these areas is also very important. Unfortunately, the small sample size of the present research does not allow me to perform statistically significant analysis nor draw strong conclusions as to the chronological sequences and relationships between the sample groups. Again, data of sites along Sakbej 1 are especially lacking. However, the ceramics and other information recovered at Cobá and elsewhere was extremely worthwhile for many reasons outlined above, and it does allow me to at least suggest likely scenarios of temporal aspects of some groups.

The San Pedro group of the Sakbej 3 terminus, for example, is of particular interest for its wealth of Tancah Burdo ceramics which place its earliest known activity in the Late Preclassic. San Pedro first pulled me in as an area of interest to excavate because of its low-lying areas that are easily flooded during the rainy season. Today the extensive ranching may obscure some of the nearby landscape as it existed in the Classic and

Preclassic periods, but the central structure of the main plaza remains an intriguing feature, as it appears to be a large conical structure. The Xaibeh - or crossroads building - of central Cobá has rounded corners, but the conical structure of San Pedro stands unique.

8.11 Data Analysis Conclusion

The above analysis of the data results serves to provide a background to delve into the deeper cultural meanings in the following chapter. The nature of this data is very preliminary, as test pits, a small sample size of water quality, and lidar data does not result in a full picture of the grand city of Cobá and its neighbors to the west. However, these data still provide a window into the ancient past, allow us to suggest possibilities about the nature of ancient life and history in the northern Yucatán, and guide ideas for future research that might help complete pieces of this picture.

Chapter 9 Discussion

9.1 Introduction

Now we are left to piece together the underlying meanings to the collected data and the importance to our questions of resilience, water management, and climate change. The evidence of various linear features in the lidar together with artifact data from test pits join with previous research of ancient drought records and previous studies at Cobá and elsewhere to provide context and illumination on the changes that the communities of Cobá experienced over time, especially in regard to the droughts of the ninth and tenth centuries AD. As mentioned briefly in the Data Analysis Chapter, my sample size of ceramic sherds is low, and thus my chronological analysis is less than robust, but the combined data still has much to offer toward better understanding Maya water management, adaptations to climate changes, and suggesting paths of action for future research.

9.2 Linear Features and Water Management

As I have shown through flow accumulation models in the previous chapter, the linear features at Cobá, Yaxuná, and along Sakbej 1 (itself being a major linear feature) serve three main purposes: to demark boundaries (for residential groups and for *milpas*), to direct the flow of foot traffic, and to direct the flow of water. Thus, they were integral components of a landscape and waterscape of which was shaped both by geological forces and human labor which helped to direct water into a variety of catchment areas that also were a fusion of natural depressions and human made or modified reservoirs.

Cobá is famous for its system of *sakbej* which facilitated trade and mobility within and to and from the city, but, like all of these linear features, they are overlooked as important water management features themselves. Not only did some *sakbej* act as dikes, as discussed previously, but many also channeled rainwaters along their sides into reservoirs, *jaltun*, and other depressions that held water. El Cerén, preserved by volcanic ash, features an earthen roadway with canals or gutters along either side of the slightly raised and compacted road (Sheets et al. 2015). These canals would have provided irrigation for the fields of maize and other crops planted alongside the road, and I suspect the *sakbej* of Cobá and elsewhere would have employed similar gutters to channel water into basins and small reservoirs, as suggested by previous scholars (Folan 1991; Scarborough 1998; Shaw 2001), as well as help irrigate fields. Today, *milpas* are often planted alongside ancient *sakbej*, both for ease of access (alongside them rather than on the roads themselves, as they tend to support thicker vegetation) and for the retention of water and good soils that form near them.

Chichbe are usually found as an elevated walkway that doubled as wall, surrounding a houselot or other type of architectural group. Such constructions would have controlled foot traffic in and around the complex and provided more privacy than *albarradas*. Contrariwise, as raised walkways they may have eased access to and from buildings for the inhabitants, especially during the rainy season. In many cases, they also served as berms that helped to divert water into catchments and cisterns, and also possibly to accumulate soil in other areas.

Sakbej-walls are a middle category between *sakbej* and *chichbe*. They resemble *sakbej* with a wall of faced stones on either side but appear less formal and straight. Their placement is more like most *chichbe*, enclosing small houselots and agricultural areas, rather than the grand wide formal *sakbej* which connect a major complex with monumental architecture to another, or to a large *cenote*. We primarily see these *sakbej*-walls at Cobá in a single grid-area of likely agricultural production focused on arboriculture, discussed below and in the previous chapter.

Albarradas are generally viewed as lot boundary markers, as they are used today to delineate houselots (*solares*), *milpas*, *ranchos*, or other territory boundaries. In general, they appear to serve such a purpose at Cobá as well. Unlike the other linear features here discussed, one does not walk on top of an *albarrada*, but they still direct foot traffic along their sides, as these boundary markers often coincide with the edges of walking paths, delineating a winding trail between them.

T'úubulbej were likely simply raised steppingstones that allowed ease of foot traffic in muddy or flooded areas. They might also have served as the bases of elevated promenades or boardwalks built of tree branches and/or other perishable materials, of which only the boulder foundations remain. This assessment is largely based on the fact that they are primarily found in low lying areas that are and were prone to flooding, many disappearing into water bodies during the rainy season. Rather than demarcating boundaries or retaining water or soil, *t'úubulbej* would have served for just the opposite, allowing movement over and across water bodies or swampy or flooded areas while disturbing the flow of such water as little as possible.

In some cases, either an *albarrada*, *chichbe,* or *t'úubulbej* connects one structure to another (or to a major *sakbej*) as a kind of crude walkway or bridge. This discrepancy of which type of feature such a connection takes could in part be due to the amount of time, labor, or resources of each community, but I suspect that it had more to do with intentional water management preferences. *Chichbe* would divert accumulated rainwater entirely to either side, while *albarradas* would only slightly divert the flow of water, and finally *t'úubulbej* would allow the majority of water to flow unhindered.

Occasionally, one of these categories abruptly transforms into another along the same line/course. Both *chichbe* and *albarrada* construction methods may complement one another to complete a houselot group enclosure, for example. When *t'úubulbej* are involved in these switches, usually this is accompanied by a slope in the landscape, with *t'úubulbej* found on the lower end, again leading to the assumption that the *t'úubulbej* were placed along areas prone to flooding or perpetually wet.

Figure 9.1 Road construction in contemporary Cobá town.

In some cases, smaller or simpler linear features may have been later built up to more robust or formal features. For example, a *chichbe* might have been built around the boulder steppingstones of a former *t'úubulbej* (or between parallel lines of them). I saw just this scenario play out in contemporary Cobá. In 2018, the heavy rains caused flooding which surrounded a house of modest construction built within a *banco de materiales* (Figure 9.1). To access the house, community members laid down large boulders which acted as steppingstones - a contemporary *t'úubulbej*.

However, this was not the intended end result, and by late in the rainy season (corresponding with our field season) they had already begun to fill in the walkway with a road made of rock, gravel, and dirt; in other words, a contemporary *chichbe*. By the time I returned in 2019, they had completed the road (Figure 9.2), although early in the rainy season of that drier year it was not as necessary, as the waters had not returned to reflood the area.

Figure 9.2 Completed road in 2019 Cobá.

Finally, and most importantly for water management, some *albarradas*, *chichbe,* and *t'úubulbej* lead directly to *cenotes* or other water bodies, or to architectural features that were built into depressions and likely acted as small reservoirs, or cisterns if they had coverings. Most such features are annular, some of which may have instead (or also) been used as pit-kilns for lime plaster production such as those at Kiuic (Seligson et al. 2017), but based on the number, placement, and morphology of those that I encountered, I propose that the vast majority were indeed small reservoirs. Of note, the linear features leading to *cenotes* and natural water bodies are most often *t'úubulbej*, while those connecting to reservoir constructions are more often *chichbe*, indicating that *chichbe* may have also been used like *sakbej* to channel water into the reservoirs.

The sheer number and density of linear features at Cobá is uncommon in the Maya sphere. While the vast majority of features digitized were *chichbe* and *t'úubulbej*, the lines between these features blur (review Chapter 6), and I suspect that many *chichbe* and especially *t'úubulbej* doubled in function as *albarradas*, of which very few were digitized, but which are labeled as such by previous researchers at Cobá (Benavides Castillo 1981a; Folan et al. 1983; Gallareta Negrón 1981, 1984). *Albarradas* are also common and numerous as residential group markers at the sites of Chunchucmil (Hutson et al. 2007, 2008; Hutson and Magnoni 2017; Magnoni et al. 2012) and Mayapán (Bullard 1952; Smith 1962), and as agricultural lot boundaries mostly devoid of other structures at coastal sites like Xcaret (Andrews and Andrews 1975; Con Uribe 1991). While I believe in many cases these features served as boundary markers at Cobá as they do at Chunchucmil and elsewhere, I also consider that their possible usage to direct rainwater as an adaptive strategy for water management and agricultural succor is fairly unique amongst Maya sites, at least to the extent of such a dense use of them in an urban setting.

Digitizing all of these linear features reveals a vast web connecting communities of Cobá to one another yet delineating houselot boundaries, controlling the flow of foot traffic while directing the flow of water towards catchments and agricultural areas. Analyzing these various groups in the lidar allows us to compare the roles and strategies of varied Maya neighborhoods and communities.

9.3 Lidar and Settlement

When working with large lidar data sets, it is important to keep in mind that what they create is a palimpsest map, a snapshot of what remains of the surface. Like a photograph, some parts can be blurry, while others overexposed. Most crucial for their archaeological uses, the digital elevation models represent structures and other features from many different time periods. While there is a wealth of information and knowledge to be gleaned from lidar data, we must not become too complacent in map-centric methodology (Burg 2017) nor overconfident in a state of "technopoly" (Huggett 2000:16; see also Lock and Pouncett 2017), but instead consider that they are merely heuristic devices - models that help guide the research and not a perfect recreation of reality. For these reasons, I lean heavily on chronological data in combination with lidar data when discussing settlement data below. In other words, we cannot wholly base our perceptions of site population density, political interactions, or other such phenomena on lidar map appearances alone.

However, lidar data still affords us great advantage for at least estimating many aspects of ancient settlement, including population sizes and site boundaries. Using a variety of approaches, namely: number of structures, roofed area, and number of groups, Stanton and colleagues (2024) estimate that the population of Cobá at its peak in the Late Classic ranged between 60,000 to 90,000 Cobanecos strong. As previously examined, there was abundant *milpa* land in the Cobá lidar data area to sustain roughly 40,000 citizens, so additional foodstuffs may have been imported from the growing network of satellite sites as Cobá expanded its power and sphere of influence. Alternatively, particularly high yields of maize (Nations and Nigh 1980) and other crops could support up to 70,000 people. A large urban population also necessitates some strategy for waste management. Such considerations are rarely research for the ancient Maya (Wong 2018), but one possible scenario is that at least some human waste was used as fertilizer after properly composting as "humanure" over time to avoid pathogens, a practice put in place by contemporary farmers Tepetixtla, Guerrero to avoid environmental degradation (Goretzki and García Saldaña 2022).

In addition to chronology, we must also deliberate over spatial considerations, for which lidar equips us exceptionally well. At Cobá, we can view the cluster of urban settlement stretched out along *sakbej* and around their termini monumental groups and note that in most cases settlement sharply drops off after a few hundred meters beyond these boundary markers (Stanton, Ardren, et al. 2023). Stanton and colleagues (2023) also visit several clusters that are exceptions to this pattern, with various explanations, often that they are in line with a shorter *sakbej* and might act as virtual termini if these *sakbej* were extended. One of these we dub Zone B (Figure 9.3), a cluster in southeastern Cobá, and I would here add an additional reason for this more distant constellation - a small *cenote* in its midst and a further area of low-lying terrain. Other groupings a far distance from the urban center, like Zone E to the east (see Stanton, Ardren, et al. 2023:87 Figures 3.3 & 3.4), may indeed be beyond the bounds of Cobá proper, and can be conceptualized as a hinterland settlement that was nevertheless associated with the city for its relative proximity.

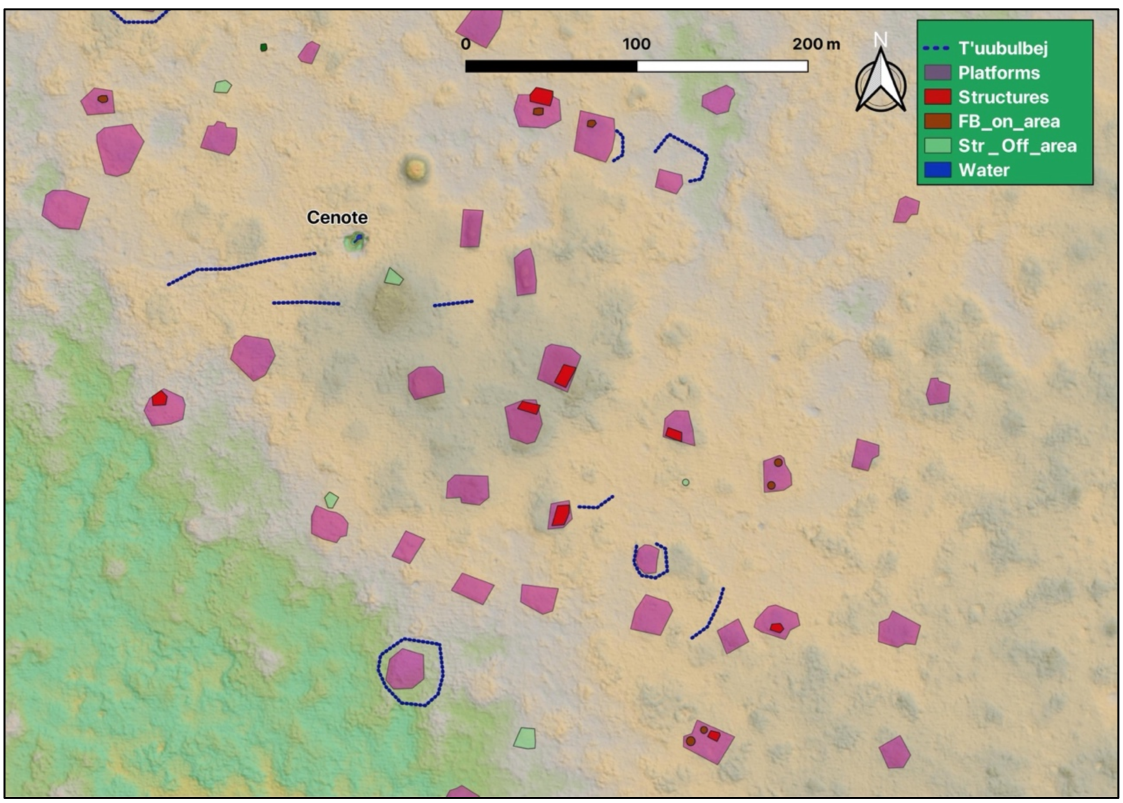

Figure 9.3 Zone B of Cobá.

Above and throughout this work I have used terms like "hinterland," "urban center," and "localized" to describe various kinds of communities and their water management practices. Garrison and colleagues (2019) posit that loaded English terms like "rural" carry connotations that likely did not apply to Maya settlement and lifeways, and that Maya researchers tend to either focus on elite royal chronicles or hinterland households and agricultural affairs, a dichotomy that may be formed more by research goals and foci than by the reality of Maya settlement. While I largely agree with this assessment and with the interpretations of their work at El Zotz, I am not convinced that their replacement with a conurban model and regional coordination necessarily applies to all Maya communities everywhere. I propose that some Maya communities did indeed possess "a hint of autonomy and anarchic (or heterarchic) localism" (Garrison et al. 2019:143).

Clearly, the integration of the communities along Sakbej 1 into the polity of Cobá in the Classic Period did not exhibit a high degree of autonomy. However, we can observe several features of the grand *sakbej* and its associated settlements that may speak to the degree of integration into the Cobaneco political sphere. These features differ over space between Yaxuná and Cobá, but also through time, as discussed below.

First, Sakbej 1, although a formal and massive work of engineering, does not appear to be uniform from one end to the other. In general, the road becomes much more straight and rigid over longer distances as it approaches Cobá, while it tends to snake and bend much more towards the middle of its almost 100km length. As it approaches Yaxuná, Sakbej 1 again grows more rectified, but not to the same extent as near Cobá. This is logical, as Cobá is a city full of intrasite *sakbej*, and is the center of power from which the impetus to build Sakbej 1 originates, but this change in quality or style of construction reveals additional political and social undertones. On the one hand, it demonstrates that labor crews for construction of the *sakbej* were likely local and pooled from the communities along the road, indicating that Cobá probably utilized a system of corvée labor and thus exercised considerable power amongst these communities. On the other hand, however, the lack of consistency in the quality, size, and rigidness of Sakbej 1 when it enters hinterland territory also seems to indicate either some level of autonomy amongst those hinterland communities, or at least a different degree of cooperation and labor practices than among the communities closer to the urban centers. The *sakbej* still tied the hinterlands to the political domination of Cobá, but it appears they were not entirely subsumed under the same kinds of city planning and organization, based on these settlement patterns.

The second major feature is that of architectural alignment toward Sakbej 1. Settlements nearer to Cobá such as Oxkindzonot and Hay-Dzonot sport plaza groups directly along the *sakbej* and oriented towards it. This tendency toward architectural orientation toward the *sakbej* becomes less pronounced and less common in relation to distance from Cobá, again until nearing and within Yaxuná, and again to a lesser degree than the roadside communities nearer Cobá. There are some exceptions; Ekal, a large site relative to most settlements near the center of Sakbej 1, boasts a massive structure directly along the road that appears to have been built after the sakbej was no longer in use, as it engulfs the former road and much of the sakbej on either side of it has been almost entirely robbed of stones and material for later construction. It would appear that Ekal might have been an important site along Sakbej 1 connected to Cobá during the height of Cobá's power, and then continued to flourish after the fall of Cobá, not sharing its political and demographic downturn fate, at least not at that same time.

Third, in addition to the network of intrasite *sakbej* of Cobá is a web of linear features made up primarily of *t'úubulbej* and *chichbe* (discussed above). These would have been useful in managing small water features like *jaltun*, catchments, reservoirs, and seasonal aguadas. Additionally, they double as walkways and connect the populace of Cobá to the *sakbej* system and facilitate the movement of people and goods. Such linear features are found along Sakbej 1 as well, but they exist in far greater number and density within Cobá and its closest outliers, such as Oxkindzonot. The predominance of the features is important on its own, as such a network of walkways and other linear features is not exceedingly common outside of a handful of sites such as Chunchucmil, Mayapán, and Becán (see Thomas Jr. 1981). Though *albarradas* are common at many sites, they do not form the same kinds of patterns as at Cobá which connects the city in such a cohesive way. On the contrary, most *albarradas* act as houselot borders and barriers rather than roads. *Chichbe* and *t'úubulbej*, however facilitate foot traffic and thus integrate Cobá to a greater degree perhaps than other Maya cities.

The above spatial settlement analysis deals primarily with the Classic Period, especially the Late Classic, as Sakbej 1 was constructed early in the Late Classic. Before the construction of Sakbej 1, in the Preclassic and Early Classic, these early settlements surely experienced a higher degree of autonomy. With the placement of the road, they enjoyed a current of traders and other travelers, and the goods and opportunities that came with them, although this also likely meant a tribute of some form that was excised the way of Cobá. During and after the crises of the Terminal Classic, some of these hinterland communities may have regained some autonomy and heterarchy as they struggled to survive under pressure. The robbing of *sakbej* stones and other materials to serve local interests (at sites like Ekal) clearly demonstrates a restructuring of the power dynamics in the region. If it were simply another polity taking power, the road would have been repaired and maintained.

9.4 Resilience, Sustainability, and Climate Change

What does this evidence teach us about resilience of socio-ecological systems with respect to water management strategies, societal organization, and political dominance (or lack thereof)? To determine this, we will need more testing and data from sites along Sakbej 1. If other smaller sites like Ekal were thriving in the Terminal Classic and beyond, that may indicate that something about the rigid state structure of a large polity like Cobá yielded it less resilient through ecological turmoil like large scale drought.

The many pitted areas, *sascaberas*, and quarries which expanded Lake Cobá (especially to its northwest) and Lake Macanxoc (mainly to its south and southeast) likely began to be excavated as early as 850BC, when maize was first grown around these lakes (Leyden et al. 1998). Centuries later, when as population rapidly increased in Cobá during the Late Classic, such endeavors would have increased, both to extract building materials and to purposefully expand the lake to create a greater production area for lakeside *milpa* farming. Both outcomes would have benefited the populace of Cobá as it managed its growing lake. However, Lake Cobá was diked around 720AD (Leyden et al. 1998), either in reaction to drier conditions, saltwater intrusion, or merely urban growth closer to the central lakes. In any case, both the expansion and later diking of the lakes was indubitably the prerogative of the state organization and dynastic elite of Cobá, a project that stopped paying dividends when the droughts began to set in a century later. While these water management strategies were meritorious at the time, they did not foresee nor prepare for long term climate changes, instead a reaction to current conditions.

Smaller sites with less state organization might have been spared such calamities. However, even if it holds true that Sakbej 1 communities were resilient through the end of the Classic, a number of alternative explanations remain possible. There may be hydrological niches (such as *cenotes*, *ts'aats'*, and caves) in the landscape along Sakbej 1 that lend those areas to ease of resilience during drought. Some of these may be undetectable with lidar in its current incarnation. In his early expedition, Bennett (1930:360) discovered three *cenotes* near the *sakbej* "about five feet wide at the top and from fifty to seventy feet to the surface of the water," whose small openings are rarely detected through aerial lidar.

Regardless of such niches and water sources, the lower population density and population in general in hinterland areas would not be as taxing on hunting and gathering from the surrounding *k'áax* (wilds), so they would inherently be less dependent on agriculture and thus less prone to famine, malnutrition, and other population disasters. More germanely, there is a dearth of linear features at these smaller Sakbej 1 sites relative to those found at Cobá. Therefore, the residents of such sites were devoting less time, labor, and resources toward manipulating the landscape for the purposes of water management. This indicates that they were able to sustain themselves with water, agriculture, and other resources without the need for the elaborate and impressive civic projects at Cobá that might have contributed to the vulnerability of Cobanecos and Cobá state systems during the droughts. These factors must be kept in mind when acquiring new data and assessing the relative resilience of various communities and social structures.

Within Cobá itself as a sprawling city, there also appear to be discrepancies with approaches toward interactions with water features. The central core of Cobá with its monumental architecture, situated along the northeastern edge of its lakes and lagoons, benefits from those lakes, from a few small and medium sized *cenotes*. The Nohoch Mul complex (Figure 7.27) is positioned on the edge of an elevation rise (as are many causeway termini), accentuating the great height of its structures and seated in an area from which rainwater flows down toward the central plazas with low lying ballcourts and eventually into Lake Macanxoc. The initial outpouring from Nohoch Mul is strongly evident in the flow accumulation models (Figure 7.52), but the tourist paths and their borders along with other formation processes obscure and interrupt the gentler slopes of these plaza areas that I suspect existed centuries ago during the former grandeur of Cobá.

In sharp contrast, the grid of *sakbej*-walls 3km to the south of the lakeside downtown sits in a depression rather than a raised plaza, features relatively humble abodes of mostly small construction, and has only small *aguadas*, *ch'e'en*, *jaltun*, and karst pits in which to collect water. Some of these are non-anthropogenic geological and hydrological features, some may have been altered by humans, and even the more anthropogenic features like human-excavated *ch'e'en* were easily carried out at the household level without the need for state oversight. Still, the grid pattern there reflects a degree of urban planning and perhaps state influence. This is not to say that grid systems (of any kind) necessitate state power. As mentioned in Chapter 2, even urbanism itself may exist without state control, and early cities with grid formations such as those of Indus society were not necessarily the product of state formation (Green 2022). However, this level of site planning in Maya settlement patterns often signifies political ideology through a physical manifestation of their cosmovision (Ashmore 1989, 1991). This grid-area, though, seems to have less to do with cosmovision (which instead is seen in monumental groups like Nojoch Mul) and more with expedient division of the landscape for some end within this grid zone. Rather than yield to the natural topography and hydrology, the grid attempts to maximize land use and movement, and may indicate a special agricultural zone with greater control by the elite of Cobá, for uses of either economic export, elite consumption, public ritual feasts, or all of the above. The many *ch'ich'* mounds in this area corroborate this idea, lending the area suited for arboriculture, other agriculture, and perhaps apiculture, and advancing the ideas of Cobá as a forest city of agrarian urbanism (Folan et al. 1983). While this model was sustainable (see Isendahl and Smith 2012) for many years, it ultimately succumbed to climate change.

The *sakbej* termini also each have their own peculiar arrangements, layouts, and relationships to water. The residents of the grand monumental complex of Kukikan, at the terminus of Sakbej 8, enjoyed what appear to be at least three small pools or baths - one on the western end of the front northern plaza, and two behind the twin monumental structures in a smaller plaza to the south. These baths are depressed circular areas approximately 5m in diameter and ringed with stones, but their location and construction indicate luxury usage rather than functioning as kilns or other production areas. Future excavations of these features could prove worthwhile.

While not as large as Kukikan in structure size or grand plazas, Kitamna dominates its *sakbej* terminus area with a fairly large structure. The nearby Kitamna *ts'aats'* once sported an equally impressive large stone stairway leading 15m down toward a platform and altar within the lower inside of the *ts'aats'*, about the same height as the main structure of Kitamna itself. Within this impressive vestige of a *cenote*, at the southern end where cool dark water remained, rituals were conceivably conducted with onlooking public spectators and/or participating religious pilgrims.

The northern termini seem somewhat less grandiose than Kukikan and Kitamna. Machukaani, at Sakbej 26 terminus, has no plaza to speak of, and is more focused around Cenote Cacahuate and the ranged structures thereof. In fact, its name translates to "incomplete." San Pedro, at Sakbej 3 north terminus, has a long welcome plaza and a large conical structure, and other small structures in the area, but no large water bodies other than the expanse of easily flooded depression behind it to the north, and some small *aguadas* and *ch'e'en* nearby.

These variations in settlement at Cobá reflect congruent variations in community makeup and social structure, along with their interactions with water bodies, rain, and water management strategies, signifying the highly organized and hierarchical society of Cobá writ large upon its urban landscape and waterscape. Near the main lakes, a hub of political power, economic exchange, and ritual sport dominate. In low-lying swampy or flooded areas away from the impressive centers and termini, networks of *chichbe*, *t'úubulbej*, and *sakbej*-walls facilitate traffic and move crops and other goods produced in those areas while also channeling rainwater into the appropriate areas. At some *sakbej* termini, magnificent monumental groups conducted ritual activities in deep *ts'aats'* and caves, and/or on the plazas themselves. At other termini, humbler communities with unfinished roads or long forgotten grandeur remain.

9.5 Drought and Vulnerability

How might each of these communities responded to the disasters of drought and other environmental and social calamities at the onset of the Terminal Classic? To determine this, I analyze the chronological data from ceramics and architecture at each group and compare them to the location and type of settlement and community. While there is considerable data to weigh and consider, the overall sample size of ceramics in this research is relatively low, and future excavations at Cobá (both near these discussed groups and at other areas), Yaxuná, and sites along Sakbej 1 will help us solve some of these chronological issues and garner a better understanding of the variations in occupational histories at the level of smaller communities.

The San Pedro terminus group (Figure 7.30) holds ceramic data as anomalous as its architecture. Unlike the bulk of Cobá, which tends heavily towards ceramics in the Palmas Complex of the Late Classic, at the height of Cobá's political power, the test pits at San Pedro show a greater weight toward the Añejo Complex of the Late Preclassic, the Blanco Complex of the Early Classic, and the Oro Complex which straddles the end of the Late Classic, the whole of the Terminal Classic, and even the start of the Early

Postclassic. There is a light representation of the Palmas in one of the test pits, so the area was not unoccupied in the Late Classic, but it appears activity here was restrained relative to other eras. It would seem, then, that the chronology of the San Pedro group is the opposite of what we would expect from Cobá overall, in that the Late Classic is underrepresented while Preclassic and Terminal Classic remains are more prominent. Perhaps this area was not as heavily impacted by the major droughts at the end of the Classic Period. Alternatively, it may have been quickly reoccupied not long after the political decline of the kingdom of Cobá by smaller non-urban populations dwelling in and amongst once majestic structures of the now fallen city. In other words, "in Deleuzo-Guattarian terminology, without kingship as an apparatus of capture, the farming communities *deterritorialised* and *reterritorialised* elsewhere as new hydrosocial becomings. Hence, the 'Maya collapse' involved the disappearance of some machines, but not of the Maya world" (Normark 2019:135 emphasis in original).

As for the higher Preclassic representation, it is feasible that as agricultural and water management strategies shifted in the wake of Cobá state formation, the San Pedro area became less important as an area of crop production, in favor of the *sakbej* wall area to the south. It may also be the case that routes to the north were deemphasized at this time in favor of the major traffic from Sakbej 1 to the west, and perhaps from the east coast, so that trade routes shifted, and the northern *sakbej* termini groups lost prominence. In the Preclassic, when many sites of the Yalahau region to the north were at their height, settlements in northern Cobá that eventually grew into these northern termini groups might have been situated in more favored territory along these routes between Yalahau and the Cobá lakes.

Vista Alegre Estriado also appears at most of the other test pit groups, but with greater representations in some excavations than others, unsurprisingly. At the Sakbej 3 & 26 intersection near Cenote Ya'axche' (Figure 7.2), only a handful of sherds were found, but most of these (11) were of various Palmas Complex types, and only three (3) were Vista Alegre from the Oro Complex. Based on this scant data, there was at least some occupation at this group not only in the Late Classic but also continuing into (or reoccupying during) the Terminal Classic.

By contrast, the midden of Kitamna held an abundance of ceramic sherds along with other materials. There the vast majority (80) of the sherds were of the Palmas Complex, with most of those (66) being Encanto Estriado: Sacná. Only 16 sherds were Vista Alegre type, but this still suggests a later occupation using the same trash pit as their Late Classic predecessors.

Within the Kitamna *ts'aats'*, or Dzadz Iox, a significant amount of type Cetelac Desgrasante Vegetal sherds were recovered (10 within the test pit and 15 from surface collection), of the Blanco Complex. The great majority here again were Palmas (only 7 in the test pit but 181 from nearby surface collection), and most of those were Arena Rojo type. A scant few (2 Holactún sherds) were from the later Oro Complex. The significant Blanco Complex showing highlights the importance of this *ts'aats'* to the earlier inhabitants of Cobá, and the mass of Arena Rojo further emphasizes its role continuing into the Late Classic kingdom, when likely the enormous stone stairway was built down into the pit. The ceramic monkey head figurine fragment indicates that rituals were performed here, and the surrounding architecture suggests that these were public displays, perhaps with elite audience members and/or participants down within the *ts'aats'* and commoners looking on from up above. However, there is not necessarily an indication of heightened ritual activity at the onset of the droughts. While a large amount of Arena Rojo *olla* sherds was found along the bank of the watery portion of the *ts'aats'*, that is to be expected from a place of water collection. During significant droughts, the water level would have dropped below the surface of this particular *ts'aats'*, and the dry remnants would not have been an appetizing place to appeal to Cháak.

A similar scenario exists for the similarly sized and shaped Dzadz Ion. While the associated surface architecture is not as grand as that of Kitamna, and there is no *sakbej* nearby, their does exist a relatively large structure on the western edge above the *ts'aats'*, another grand staircase on its northern end to access the bottom, and a structure down in the pit near the water to its south (Terry et al. 2022). The surface test pits near the *ts'aats'* represent a somewhat even distribution of sherds from the Palmas (67) and Oro (70) Complex sherds, with only a few from Añejo (7) and Blanco (2). While the test pits within Dzadz Ion orchestrated by Terry and his colleagues (2022:11) contained Palmas Complex sherds (Vista Alegre, Batres, and Cetelac types), they also found Late Postclassic materials (Navula, Yacman, and Chen Mul), including fragments of Chen Mul *incensario* figurines complete with ceramic cacao pods. Such censers are often found in cave shrines and altars, and their presence here indicates that Dzadz Ion was an important agricultural and ritual asset through many epochs of Maya history at Cobá, even if by the Late Postclassic this area was primarily used for pilgrimage rather than for domestic (let alone urban) settlement.

Notably, though, there is a dearth of Oro Complex ceramics within Dzadz Ion, even though nearby surface test pits did contain Oro sherds, the first part of which corresponds to the great droughts of the ninth and tenth centuries, indicating that the water table within the *ts'aats'* might have lowered considerably, resulting in devastation to cacao and other plants within. However, if Dzadz Ion and/or Dzadz Iox indeed went dry during that time, it did not entirely prevent occupation. The inhabitants may have made do through the drought, but their source of easy currency growing on trees suffered, leaving them less wealthy and sans chocolate. The impact of the drought on Cobá is starting to look like more of a defeat to its economic and political might than an out and out famine. In other words, using the language of Walker and his colleagues (2004), the overall resilience of human survival at Cobá was secure, but the panarchy of a host of subsystems that exceeded their latitude resulted in a failed resilience of the hierarchical social system of Cobá as it existed in the Classic, especially its economic success. If, during droughts, *ts'aats'* and *rejollada* subsystems fail to provide cacao and other niche fruits (e.g., avocado) that can only be grown in particular environments, that in turn would disturb trade networks and could bring down the might of the political and financial elite of Cobá, and ultimately undermine the kingdom as a political powerhouse, from within and/or from without.

With that in mind, how might drought have tested communities closer to the water table? Ceramic sherds from the area of the *sakbej*-wall grid area date primarily to the

Palmas Complex, the seventh and eighth centuries AD representing the heaviest occupation there. A decline in ceramics from later centuries may correlate with the droughts of the late ninth and much of the tenth century. As in the *ts'aats'*, these areas in wide depressions close to the water table might have been cultivating fruit trees supported by *ch'ich'* mounds until their roots could find that aquifer, and possibly even cacao sheltered by the *sakbej*-walls. Soil testing in this area in future projects might prove fruitful.

Roughly 1km northeast of the grid area we dug two test pits near two ranged structures to the north and east of Cenote Sinacal. These test pits (210A and 210B) are more in line with what we might expect from general occupation at Cobá. While 210A had a modest quantity of artifacts, 210B held the largest number of sherds of any test pit, despite an average depth and volume relative to other test pits dug that season. One of the more interesting sherds was a single large rim piece of a Kuche vessel, a Mamom style dating to the Middle Preclassic (Andrews V 1988; Bey III et al. 1998; Rissolo et al. 2005; Stanton and Ardren 2005), roughly 600-350BC, the earliest of any in my excavations at Cobá for this present research. It also contained a single Chancenote Estriado sherd (also unique in my excavations), dating to Robles' (1990) Añejo Complex, a couple of Cetelac dating to the Blanco Complex, a large mass of sherds (116) from the Palmas Complex, and 19 Vista Alegre sherds from the Oro Complex, showcasing a long history of occupation at this area. Still, the overwhelming majority is from the Palmas Complex, telling the typical story of a slow build of early history at Cobá, an explosion of population in the Palmas, and a remnant population after (and/or during) the droughts of the Oro Complex.

The big question remains whether such a remnant population was truly remnant and stayed through the droughts, or whether it was new communities of people moving into the ruins of Cobá decades or even centuries after the devastation of the droughts. It is my considered opinion that the city of Cobá was never fully abandoned in the Terminal Classic or during the droughts of the ninth and tenth centuries AD. However, their political and economic might have been toppled by those droughts, as discussed above by way of cacao failures in *ts'aats'* and *ko'op*. Sakbej 1 appears to have been abandoned by the eighth century AD (Stanton, Magnoni, et al. 2020), and the latest known date carved upon a stela at Cobá is 780AD (Guenter 2014), suggesting the final vestiges of dynastic rule ended not long after, and the state of Cobá ceased. However, occupation continued, even if the population was severely reduced in the ensuing centuries.

While the political might of Cobá and other polities waned in the eighth century and had fully depleted by the ninth, other sites like Chichén Itzá were only just beginning to flourish in those years. It may be that the microenvironments and landscape limnology of Chichén Itzá allowed for the continued growth of cacao and other economically important plants through those periods of drought, or that the droughts were not as severe in that and other localized areas, and that large portions of populations migrated out of failing cities and toward blossoming ones like Chichén Itzá. The *rejolladas* and *ts'aats'* of Chichén Itzá may have been closer to the water table through that era, and/or that region may have received more rainfall than others.

From Yaxuná we see an abrupt shift from the Cobá dominated era of east coast style architecture (beginning around 550AD) to a new Puuc style around 700-750AD (Ambrosino et al. 2003; Novelo Rincón 2012; Stanton, Magnoni, et al. 2020), indicating the western expansion of the might of Cobá was already waning at this point in history. We also surmise, despite much debate on its chronology over the years (see Andrews V and Sabloff 1986), that Chichén Itzá quickly rose in might in the tenth century (Andrews and Robles Castellanos 1985; Ringle 2017; Stanton, Magnoni, et al. 2020), and eventually replaced possible Puuc influence at Yaxuná and became the dominant center in the region while many other local sites dwindled (Stanton, Magnoni, et al. 2020), suggesting their populations may have relocated toward Chichén Itzá around the late ninth to early tenth centuries. Indeed, Yaxuná was largely abandoned or had a very small population at this time.

The geology and terrain around Yaxuná and Chichén Itzá is quite distinct from that of Cobá. Though still part of the large flat karstic north, this more interior area is not as low-lying as Cobá, and only touches the water table via *cenotes* that are far from the surrounding ground surface, while the area also has many geologically formed humps and ridges. Perhaps because of these differences, the linear features so prevalent at Cobá are far rarer at Yaxuná, Chichén Itzá, and many other inland sites. It is possible that the drought was not as severe around Chichén Itzá, allowing them to benefit in the aftermath of the downfall of other centers. In addition to their Sacred Cenote and other *cenotes*, many *rejolladas* dot the Chichén landscape, in which cacao were certainly cultivated, as indicated in the friezes of the Temple of the Owls (Taube et al. 2020). This far inland, the *rejolladas* and *ts'aats'* would have been less vulnerable to saltwater intrusion. The area is also situated between the Anillo de Cenotes to its west and other geologic faults to its east (see Figure 9.4), conceivably resulting in a more robust aquifer at a confluence of slow underground hydrologic flow. In other words, owing to their position on the landscape, Chichén Itzá and its immediate neighbors might not have needed to devote as much labor toward water management in general, nor been as challenged by the ravages of the droughts.

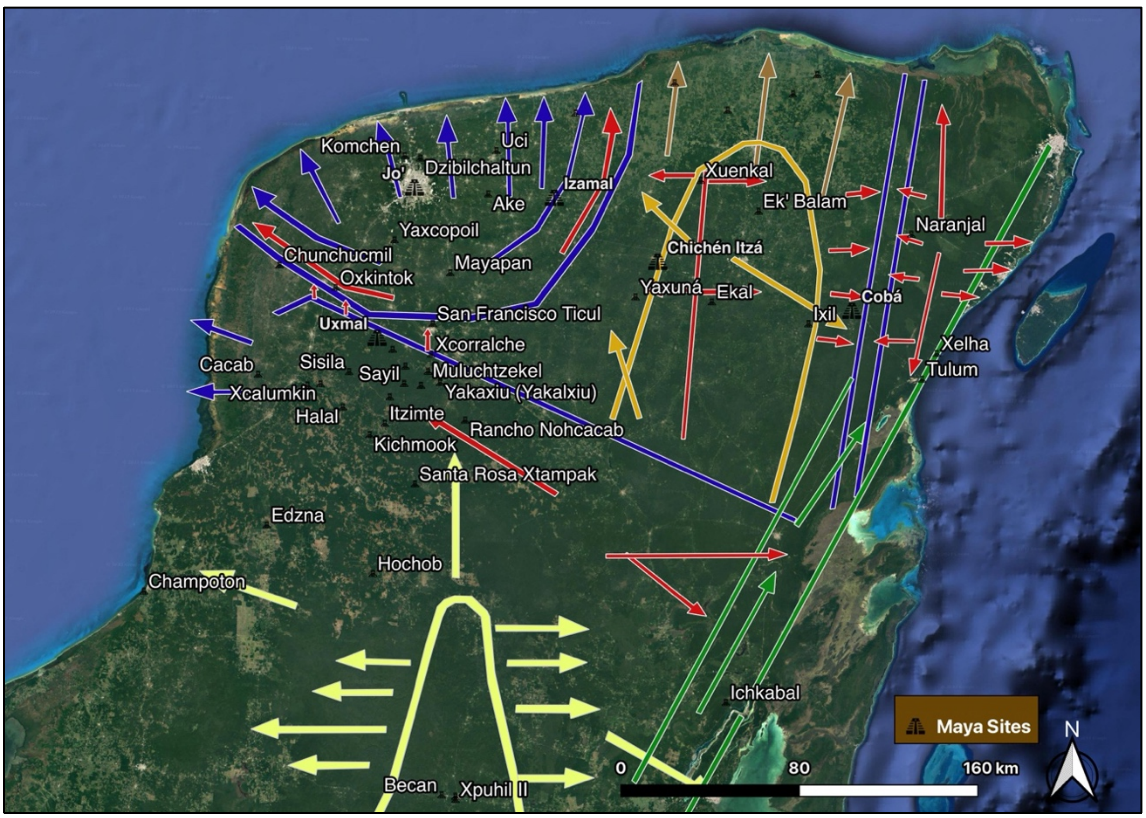

Figure 9.4 Underground flow of water influenced by elevation, fault lines, and coastal proximity.

Back east, however, Cobá had truly felt the weight of the droughts and had a diminished population that traded with and/or migrated from smaller sites to the north and east like those of Yalahau, and thus ceramic materials from this era are mostly Vista

Alegre type, yet greatly reduced in count and weight from the amounts we see from Arena Red, Batres, and other types from the preceding Palmas Complex before the droughts. As Cobá waned, Ek' Balam to the north became the dominant power in the region in the late eighth and early ninth centuries (Bey III et al. 1997, 1998; Lacadena García-Gallo 2004). In fact, the dynamic Ukit Kan Le'k Tok' became *ajaw* of the Talol kingdom centered around Ek' Balam in 770AD (Lacadena García-Gallo 2004; Martin and Grube 2008) under the patronage of the *xaman kaloomte'* (high king in the north), likely arriving from abroad to initiate that dynasty (Martin 2020:127–128). Eventually Ukit Kan Le'k himself ascended to the rank of *kaloomte'* (Lacadena García-Gallo 2004:100), which shifted the predominant northern Maya seat of power from Cobá to Ek' Balam.

By the ninth century Cobá appears to have declined in power, reeling from droughts and devoid of *kaloomte'* and major economic wealth. It may not have been particularly appealing for outside conquest, as the droughts continued and increased well into the tenth century and the site was further abandoned, although it is possible some of their former inhabitants migrated towards growing powers like Ek' Balam. Later, in the Postclassic, Cobá did see a resurgence of activity enough at least to build the Pinturas Structure (Robles Castellanos 1990:46) and hold a lively (if non-permanent) marketplace (Coronel et al. 2015). However, these activities indicate primarily ritual activities and emphasize Cobá as a place of pilgrimage during the Postclassic, with no evidence to date of permanently occupied dwellings during that era. Therefore, in the end, we can say that the Maya people and culture of Cobá had some degree of resilience through the crises of the droughts, but that their hegemonic structure and economic power were far less resilient and met their end in part to the fragile *ts'aats'* and *ko'op* ecosystems and thus the loss of cacao and other crops vital for the economy but less vital for human life.

9.6 Discussion Conclusion

Previous researchers (Dunning et al. 2012; Torrescano-Valle et al. 2019) have highlighted the variability of both the severity of droughts and climate change throughout the Maya region, and the human responses to those crises in different regions and sites. The present research demonstrates that there is further variability even within a single site due to niche environments like *rejolladas*. More significantly, my research emphasizes the marked difference in resilience depending on what system(s) we focus: the socio-ecological system, the political, economic, agricultural, or urban. Drought takes its heaviest toll on water management systems, and that in turn influences the rest of these, primarily through agriculture yields.

Ancient Maya agriculture cultivated a wide assortment of plants - some for foodstuffs, others for economic value, others for harvesting materials, others for medicines, and some that provided more than one of the above. When droughts impacted the Maya, they could adapt and survive with alternative plants for foodstuffs (see Fedick and Santiago 2022). For very mild droughts, the three sisters could still be viable, especially with varieties of maize like *nal xooy*, which can mature in two months with less water. More extended and/or severe droughts, however, would require changes to the dominant crops in order to avoid starvation or malnutrition. Mamey, ramon nuts, and amaranth could sustain short droughts, and the latter two of those may be stored for long periods. Chaya (a very nutritious plant, see Panghal et al. 2021), malanga, and sweet potato could sustain moderate droughts, and in extreme droughts the Maya could still turn to heart of palm or manioc. Of course, it is not easy to drastically change planting habits from one year or season to another, or to forage in the *k'áax* for enough heart of palm and other wild foods sufficient to feed a city. Different crops require different types and depths of soil and mature at different rates. All of this requires careful planning, but these alternatives do at least exist and have been utilized by the Maya in the past and today, even if they are not as predominant as the three sisters.

Devastation to economically important crops is a different matter. This would not lead to starvation, but it would upend an economic system that supported civic and political systems. Cacao, the most valuable crop in Classic Maya markets, can be finicky. It needs water year-round (but not too much), deep and well drained soils, and benefits from calcium and magnesium found in limestone and dolomite. A prolonged drought and lowering of the water table spells desolation for the cacao crop without an irrigation system.

It is possible that pot irrigation (filling *ollas* or other containers from nearby water sources) was implemented in home gardens and other circumstances by the ancient Maya, as suggested by several researchers (Fedick 2014; Gunn, Matheny, et al. 2002; Winzler and Fedick 1995; Wyatt 2014), and witnessed as an extant practice in traditional contemporary Maya households (Wilken 1987). Pot irrigation may have thus been applied to cacao and other plants through the dry season, especially when they were young and developing roots. If so, it could also operate to sustain thirsty plants through a mild drought. However, as drought conditions persisted, the difficulty of filling jars from water sources dropping lower and further from the ground surface, while some lost water entirely, would surely result in lost trees and lower yields on those that remained. In this case, there are not many viable alternatives to replace the currency that grows on trees, and the time and labor put towards tending the doomed plants would only take away from other more fruitful pursuits. Honey could be a feasible alternate with high economic value, but the *melipona* bee is likewise picky, preferring certain flowers and also enjoying regular water supplies.

In the end, the Maya themselves were resilient through the great upheavals of the Terminal Classic. Their dynamic forests and ecosystems were also resilient, continuing to adapt to the climate variations as they have for many thousands of years. Less resilient were the economic and political systems of the Maya. Cobá and its satellite sites would have struggled to produce cacao, while also dealing with food shortages and the struggle to find substitute sustenance. Through this struggle, Maya people and culture survived, but their Cobá dynasty perished, as did many others. In other words, the political power structures and paradigms of Classic Period kingdoms were decidedly not resilient. In the Terminal Classic and Postclassic there was a shift from a primacy and focus on interior polities toward that of coastal cities (Gunn et al. 2017), perhaps in part to failures in cacao and other valuable crops, in addition to diminished workforces for craft production.

Here we see a mélange in the current preponderance of the evidence uncovered on this project. In some cases, a story is told similar to what we would expect with previous research at Cobá and elsewhere, of a major occupation during the Classic Period and a waning or collapse in the Terminal. In others, we realize scenarios unique to niche environments that were important for different reasons in different epochs, and thus waxed or waned both in cultural importance and with changing agricultural strategies and responses in water management strategies to the ever-changing environment. With further investigations at Cobá and sites along Sakbej 1, we hope to further elucidate the specifics of these changes and the reasons for the variety of communities and their approaches to their hydrologic surroundings in years to come.

Chapter 10 Conclusion

10.1 Takeaways

What have we learned from the past failures and successes of Maya water management and resilience in the face of floods, droughts, and climate change? At Cobá, a large network of linear features connected its ancient citizens with ease of travel over swampy and flooded terrain through the rainy season, while simultaneously diverting water to where it was needed for the purposes of agriculture, human consumption, lime plaster, and other workshop production. At Yaxuná and settlements along Sacbe 1 there are far fewer of these linear features, largely due to a difference in landscape and waterscape, but also due to reduced and sparser populations. As the droughts of the ninth and tenth centuries dried up the landscape of Cobá, their once prudent use of these linear features became largely superfluous. The lakes shrank, the wetlands diminished, and the water lens sank and became ever more exposed and vulnerable to saltwater intrusion. Microenvironments like *ts'aats'* - where ancient Cobanecos grew cacao and other commercially and ritually important crops - saw their water table drop and such plants die or produce significantly smaller yields.

Perhaps one major lesson, then, is to diversify production in both products and strategy, and not be wholly dependent on the rains. Ancient inhabitants of Cobá were quite successful for centuries through a considerable array of diversification and adaptations to their particular environment. In addition to utilizing *rejolladas* and *ts'aats'*, they also modified the landscape to grow a variety of crops. However, the state structure of Cobá was not able to withstand the droughts, and the collapse of that social structure resulted in the large-scale abandonment of the city, whose surviving inhabitants may have migrated for better opportunities elsewhere.

Modern occupants of the *ejidos* today raise melipona bees, pigs, peccaries, fowl, and other animals, along with their *milpas* and *solar* gardens. They also employ variant cultivars of *nal* (corn), some of which grow faster (*nal xooy* can mature in as little as 2 months) and thus more adaptive toward less bountiful rainy seasons. The honey and other bee products provide the biggest payout but take a long time and delicate care to produce. Tourism also boosts the local economy, the modern-day equivalent of ancient pilgrimage to the same city.

Figure 10.1 This well at Xocen still functions but is almost always closed in favor of the well in the center of town which pumps water to the whole *kaajal*.

Today pumps are preferred over buckets for transporting water up into a *tanque* above each household for quotidian water use, with basic plumbing. While this changes the social dynamic of gathering at the well each morning, these communities are still very social and integrated, and work together to overcome problems. However, this also means that not as many people gaze down into a *cenote* or *ch'e'en* on a daily basis, or otherwise actively interact with these water sources. The relationship to the underground water is therefore altered, and pollution might more easily go unnoticed or ignored. While the plumbing saves great amounts of time and energy, it poses new challenges in the form of managing water in order to not overuse local resources and to avoid polluting the aquifer.

10.2 Future Water Crises?

While most Maya towns enjoy plentiful water from such pumps and the large aquifer beneath them, that might not always hold. Karst aquifers can be fragile, and the threat of sea level rise looms large, which could salinate the water supply, especially along the coasts, repeating the patterns of the past. To be certain, this is not simply a problem of occupants (and tourists) of the Yucatán Peninsula overusing or polluting water. In addition to local industries that operate there, the global crisis of warming contributed to by industries and emissions the world over is a risk to the integrity of the water lens of the Yucatán.

Globally there is more than enough clean fresh water for our bulbous world population, but distribution to areas undergoing climactic issues of drought and/or anthropogenic issues of mismanaged infrastructure and pollution creates the apparent scarcity led by socioeconomic pathways (Graham et al. 2020). For example, an expansion of the almond industry (and other nuts) in California despite increasing droughts in recent decades has led to unsustainable water management strategies in some drier counties where the evapotranspiration of applied water leads to concerns regarding the longevity of such practices (Vanham et al. 2020). Meanwhile, Nestlé takes water out of the drought-stricken state to transport and sell abroad (McNeish and Neufeldt 2022), clearly indicating that historical contingencies and economic incentives are outweighing common sense water management geared toward long term sustainability and resilience. BlueTriton, the parent company of Poland Spring and many other bottled water brands, has fought legislation in Maine, California, Michigan, and several other states in recent years that would protect their groundwater (Tabuchi 2023). In these and many other regions in the USA, aquifers that were thousands of years in the making have been entirely depleted or are on the verge of depletion in coming years (Rojanasakul et al. 2023).

Back in the Yucatán, the strains on aquifers there are also growing. New technologies and modeling techniques are helping us to pinpoint areas of greatest vulnerability (e.g., Moreno-Gómez et al. 2022). While much of these techniques have focused on Yucatán state and its capital Mérida in particular, the potential exists to apply such models elsewhere in the Mundo Maya, and indeed anywhere else in the world facing similar karst aquifer crises. Much of this vein of research in Quintana Roo has been in response to (or at least in consideration of) the exploding tourism industry there - e.g., the water quality and future sustainability of resources in inlets near Holbox (Rubio-

Cisneros et al. 2018). While karst systems are particularly dynamic geological phenomena, with new sinkholes forming and hydrological systems changing with sea level changes and groundwater usage, these representations might also be used to gauge possible vulnerabilities of past societies. After all, ancient urban populations also had pollution and waste, even if to a lesser extent than highly densely populated cities of today and without the degree and kind of industrial waste produced through modern global capitalism.

It is not just waste of which we need be wary. Water usage and general sustainability of ecosystems in the face of water management is key. It is possible that the dynastic rulers and state apparatuses of Late Classic Cobá were overindulgent in resource management and thus partially responsible for their own downfall, as has been proposed for other Maya cities and the Terminal Classic in general (Culbert 1973; Oglesby et al. 2010; Turner and Sabloff 2012). I am inclined, however, to see the evidence thus far presented as not a total mismanagement of basic resources like water and fuel (wood for cooking and producing lime plaster), or unsustainable agriculture. On the contrary, the complex landscape of Cobá shows long term efforts to manage these resources. Instead, the droughts proved too much perhaps in reducing some such basic resources, but moreover in drastically depriving the polity of Cobá its wealth in the form of cacao and other valuable plants, as well as a strong and robust labor force, leaving them susceptible to both inner turmoil and outer invasion or other pressures. An economic and political collapse seems a more likely explanation than that of sudden and severe starvation for the general population decline and extensive abandonment of the city beginning near the turn of the tenth century AD.

10.3 Strategies and Solutions

What is to be done? To better understand the intricacies of both my research questions and their wider societal implications for current climate crises, more research will be necessary to understand the chronologies of occupation along Sacbe 1, at various communities within Cobá and Yaxuná, and of environmental changes and impacts throughout the region. The more we understand about the mechanisms of change and the systems involved, the better equipped we will be to tackle the problems and changes facing us today.

Several organizations are working towards sustainable water resources both within the Yucatán Peninsula and all over the world. As mentioned in Methodology, the water testing kits used in this research came from EarthEcho International, which fosters education and conservation amongst youth and communities the world over with a focus on water quality and sustainability. InHerit (originally the Maya Area Cultural Heritage Initiative) and its nonprofit arm The Alliance for Heritage Conservation, collaborates with indigenous communities both to celebrate their heritage and develop programs of environmental education and protection in small communities, especially regarding their *cenotes*.

A few government projects, both Mexican federal (e.g., the Programa Especial de Cambio Climático) and state (e.g., Bitacora Ambiental Yucatán) funded, have undertaken studies on climate change and water sustainability and attempted to take action to mitigate negative effects, but too often these projects suffer from a lack of funding that is but a drop in the bucket relative to the millions of dollars thrown at projects like the "Tren Maya" and other tourism-boosting projects that are actively destroying both archaeological sites and environmental resources like the aquifer. Furthermore, these government attempts to reduce vulnerability "were found to lack continuity, be hard to access and too orientated toward commercial scale producers" (Metcalfe et al. 2020:1).

This is not to say that government efforts are doomed to failure, but that if they are to be effective and successful, they must work with local communities and scientific communities to understand the intricacies and localized challenges that each face, which as we have seen in this research can be markedly different between neighboring regions based on slight changes in elevation, climate, water access, and niche environmental areas like *rejolladas* and *ts'aats'*. The Consejo de Cuenca Península de Yucatán is a relatively young (established 2014) agency aimed toward sustainable water consumption and protection of the aquifer, which combines resources and efforts at federal, state, and municipal levels, but its long-term efficacy remains to be seen.

There are varying strategies for tackling climate change just as there are to any problem, and such strategies are heavily influenced by culture and worldview. Freidel, Schele, and Parker (1993:36) go so far as to label these varying societal visions "alternate realities" and promote the strengths of those that are often dismissed, both as a matter of equality and justice, and to "foster cleaner, more humane, and more survival-oriented forms of material power [as] a matter of common sense." How does archaeology help us to develop and support successful strategies to overcome these hurdles? Rather than merely study the ancient past to piece together a more robust and coherent history for its own sake, we must use knowledge derived from archaeological research to confront modern problems and aid in solutions. Despite difficulties, "archaeology remains the principal disciplinary division capable of judging the effects of environmental change on societal structures as well as the role of society itself on the overexploitation of environmental resources and their long-term consequences" (Scarborough 2008:24). I believe archaeological work in the northern Yucatán is particularly poised to do just that at a critical turning point in its history, as populations increase, tourists and immigrants flock to the coastal cities, and pressures are placed on both the environment and the indigenous inhabitants of Mayab.

The Yukatek Maya word for work - *meyaj* - is one of the few verbs to have two different vowels. In this case the reason is that it is a compound word meaning to cause pain/harm (*yaaj*). Working the *milpa* (*meyaj kool*) causes harm to the *k'áax* and to oneself, one's spirit/soul (*pixan*). Reciprocal action for causing such harm is built into the language and culture of the Maya. Whether farming, hunting, collecting wood, or any other encroachment into the *k'áax*, these actions must be reciprocated in kind - through prayer and/or offering - equivalent to the perceived harm. In that vein, what sort of reciprocations might the machinations of tourism and industry (and the individuals and systems driving them) grant in the wake of their harm and destruction to the forests and aquifers of Mayab?

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